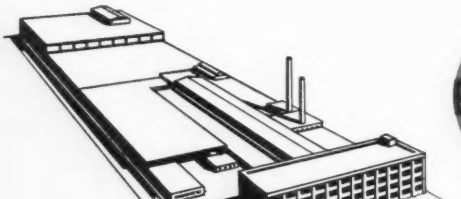
# Aeronautical Engineering REVIEW

DECEMBER, 1954

# SUNDSTRAND AVIATION DOUBLES PRODUCTION CAPACITY



SUNDSTRAND

Sundstrand Aviation is now the sole occupant of a 250,000 square-foot facility devoted to production of Sundstrand Constant Speed Drives for the aircraft industry. The move, which doubles production capacity, reflects Sundstrand Aviation's continuing policy of providing facilities to meet current commitments, as well as to anticipate future demands of the Air Force, the Bureau of Aeronautics, and engine and airframe manufacturers for the pioneer constant speed drive. It comes hard on the heels of the announcement made earlier this year of Sundstrand Aviation as a separate division of Sundstrand Machine Tool Co. And it is to be followed by other expansion moves, now in planning stages, which will provide additional facilities to meet the ever increasing demand for Sundstrand Constant Speed Drives.

## SUNDSTRAND AVIATION

Division of Sundstrand Machine Tool Company, ROCKFORD, ILLINOIS • Western District Office: Hawthorne, California

CONSTANT SPEED DRIVES • AIRCRAFT ACCESSORIES

# Aeronautical Engineering Review

Vol. 13 — No. 12 December, 1954


## CONTENTS


**Wing Design for Practical High-Speed Aircraft** ..... *Donald W. Finlay* 44

**Designing the Cockpit for High-Speed Flight** ..... *S. N. Roscoe* 47

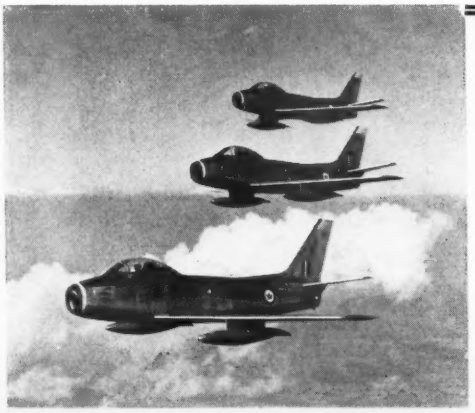
**Problems Encountered in Calculating Reliability** ..... *Lucille F. Maier* 52

**Thermal Considerations in Electrical Accessory Design** ..... *E. W. Cornwall* 59

**The Basis for Compromise Between Theoretical Performance and Operational Reliability** ..... *William D. McGuigan* 65

**Aeronautical Research and Development in Sweden** ..... *Hans-Eric Löfkvist* 68

IAS News Notes ..... 33
IAS News ..... 35
Guest Editorial by Hugh L. Dryden ..... 40
Aeronautical Reviews ..... 97
Books ..... 125
Personnel Opportunities ..... 133
Index to Volume 13 ..... 139
Special IAS Publications ..... 143
Index to Advertisers ..... 144
New Products and Product Literature ..... 147

**Cover**—Three RCAF Sabres, built by Canadair Limited and powered by A. V. Roe Canada Limited's Orenda jet engine, are shown during a routine flight. These aircraft are basically the North American Aviation, Inc., F-86E's with certain equipment differences, as, for example, the use of the Orenda engine. The Sabres are produced by Canadair under a licensing agreement between North American Aviation and the Canadian government. The Canadian government announced the delivery of the one-thousandth Sabre some months ago.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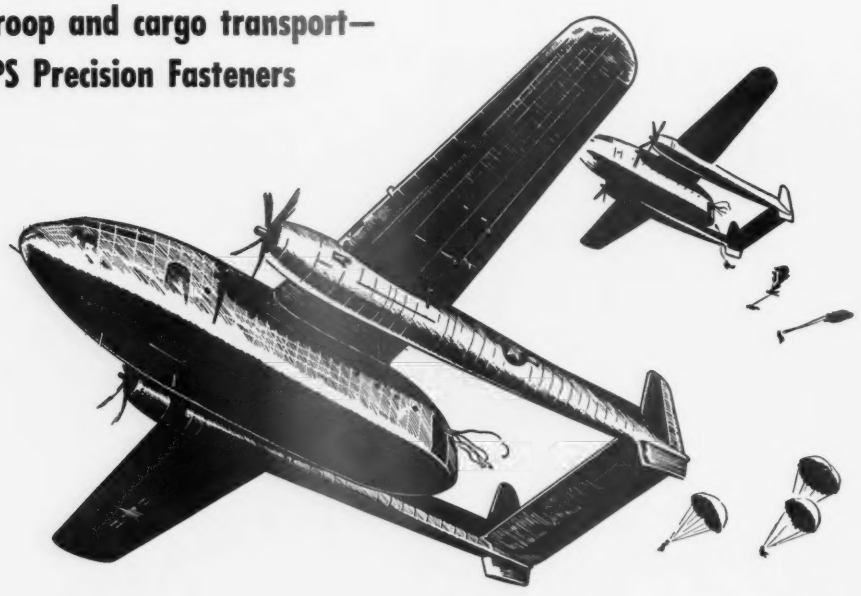

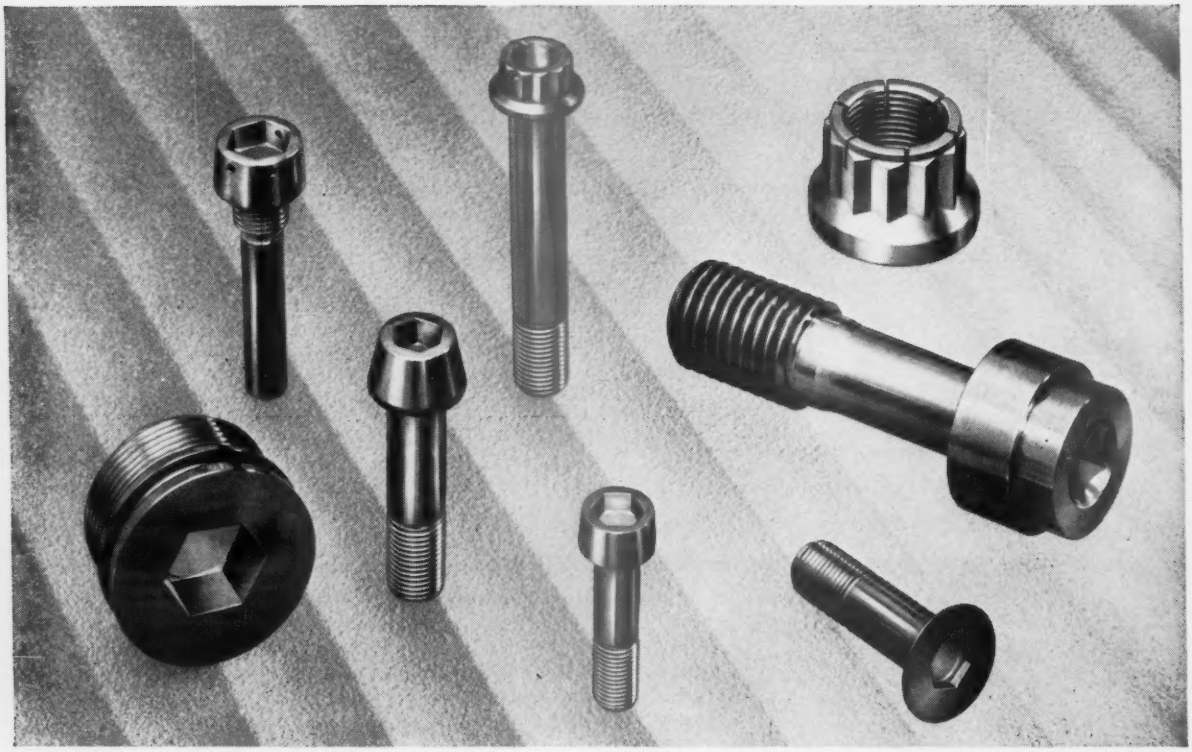

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I.A.S. News Notes

December 1954

## CONFERENCE ON HIGH-SPEED AERONAUTICS

Polytechnic Institute of Brooklyn has scheduled an important conference on High-Speed Aeronautics for the dates of January 20-22, 1955. Held in connection with Polytechnic's Centennial Celebration and the opening of its new supersonic and hypersonic laboratory facilities at Freeport, L. I., this three-day meeting will feature many well-known speakers and authorities from this country and abroad. Dr. Th. von Karman will deliver the keynote address.

Details of the technical sessions, conference dinner, and program may be obtained from N. J. Hoff, Head of the Aeronautical Engineering and Applied Mechanics Dept., Polytechnic Institute of Brooklyn, Brooklyn 1, New York.

* * * * * * * *

## PRITCHARD TO LECTURE IN AMERICA

J. Laurence Pritchard, former Secretary, and presently a member of the Council, of the Royal Aeronautical Society, will give a series of lectures on the history of aviation throughout the United States next year.

His itinerary, beginning at Polytechnic Institute of Brooklyn on January 20, will take him to more than 20 universities and institutions in all sections of the country. He will present his talk at a Historical Meeting of the IAS on January 26 during the Institute's Annual Meeting at the Sheraton Astor Hotel in New York City. A more detailed outline of his lectures will appear in an early issue of the Review.

* * * * * * * *

## NATIONAL MEETINGS CALENDAR

| | |
|---|---|
| Dec. 17 | Eighteenth Wright Brothers Lecture, U. S. Chamber of Commerce Building Auditorium, Washington, D. C. Bo Lundberg, Director, Aero. Research Institute of Sweden, Lecturer. |
| Dec. 20 | Eighteenth Wright Brothers Lecture (Repeated), IAS Building, 7660 Beverly Blvd., Los Angeles, California. |
| Dec. 22 | Eighteenth Wright Brothers Lecture (Repeated), Auditorium, Lewis Flight Propulsion Laboratory, NACA, Cleveland. |
| Jan. 24-28 | Twenty-Third Annual Meeting and Honors Night Dinner, Hotel Sheraton Astor, New York. |
| Mar. 11 | National Flight Propulsion Meeting (Restricted), Hotel Carter, Cleveland. |
| June 21-24 | Fifth International Aeronautical Conference, IAS Building, 7660 Beverly Blvd., Los Angeles, California. |
| Aug. 8-10 | Turbine-Powered Air Transportation Meeting, Seattle, Wash. |

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## I.A.S. News Notes (con't.)

### NECROLOGY

Eric Olsen, MIAS, Project Engineer, Naval Air Missile Test Center, Point Magu, California, October 17.

Charles E. Richbourg, TMIAS, Engineering Test Pilot, Convair Division of General Dynamics Corporation, November 4.

* * * * * * *

### CALENDAR OF SECTION MEETINGS

Dec. 1-- Chicago Section: Chemistry Building Auditorium, Illinois Institute of Technology. Meeting, 8:00 p.m. "The Rocket Powered Commercial Airliners" by Dr. Walter R. Dornberger, Bell Aircraft Corporation.

Dec. 1-- St. Louis Section: Engineers Club. Meeting, 8:00 p.m. Panel discussion on "Propulsion Systems Supersonic Aircraft" with panel members: Col. N. C. Appold, USAF; E. F. Pierce, Assistant Technical Director, Wright Aeronautical Division, Curtiss-Wright Corporation; and W. K. Hawkins, Chief of Thermodynamics, McDonnell Aircraft Corporation.

Dec. 2-- Baltimore Section: Room 110, Maryland Hall, The Johns Hopkins University. Meeting, 8:30 p.m. "Nuclear Energy--Its Uses and Limitations" by T. F. Nagey, Manager, Nuclear Division, The Glenn L. Martin Company.

Dec. 7-- Hampton Roads Section: Oasis Restaurant. Social Hour, 6:30 p.m., Dinner Meeting, 7:00 p.m. "More Than Engineering" by Capt. Walter S. Diehl, USN (Ret.).

Dec. 9-- Dayton Section: Aeroproducts Operations of Allison Division, General Motors Corporation, Vandalia, Ohio. Meeting, 6:30 p.m. "Turboprop Application" by R.R. LaMotte. Tour of Aeroproducts plant.

Dec. 10-- Los Angeles Section: IAS Building. "Holiday Hoedown" (Social Mixer), 8:30 p.m. Entertainment, dancing, and refreshments.

Jan. 4-- Los Angeles Section: IAS Building. Specialist Meeting, 8:00 p.m. "Flame Stabilization" by Frank E. Marble, Jet Propulsion Laboratory, California Institute of Technology.

Jan. 11 -- Indianapolis Section: Allison Division, General Motors Corporation. Dinner Meeting. Program to include visit to Powerama Exhibit.

Jan. 17-- Los Angeles Section: IAS Building. Confidential Specialist Meeting, 8:00 p.m. "Heterogeneous Fuselage Construction for Large Missiles" by Dr. Adam T. Zahorski, Aerophysics Development Corporation.

Mar. 1-- Indianapolis Section: Tentative plans include talk on "Application of Nuclear Energy to Aircraft Propulsion."

* * * * * * *

# IAS News

*A Record of People and Events of Interest to Institute Members*


## IAS Twenty-Third Annual Meeting

### *Technical Program Gives Promise of Drawing Wide Interest from Aircraft Industry. Other Engineering Groups Cooperate in Sessions.*

THE TWENTY-THIRD ANNUAL MEETING of the Institute of the Aeronautical Sciences will be held at the Hotel Astor in New York from January 24 to 28, 1955. The Honors Night Dinner will take place as usual on the evening of the first day of the meeting in the Hotel Astor's Grand Ballroom and will be the scene of the presentation of the IAS annual awards and honors. J. L. Atwood, IAS President and President of North American Aviation, Inc., will be the Toastmaster at the Honors Night Dinner.

The program planned for the 1955 annual meeting promises to be one of the most interesting ones that the Institute has yet presented. In addition to the regular technical sessions, there will be some sessions on themes infrequently covered at IAS annual meetings. These new themes will be on aircraft noise, aircraft instrumentation, and JATO for aircraft. Also, the electronics in aviation sessions should be of wide interest.

**Aircraft Noise**—The session on aircraft noise, tentatively scheduled for January 25, will be under the joint sponsorship of the Acoustical Society of America and the IAS. Four papers are to be delivered at this session. They will cover British and American work in this field, acoustic radiation from boundary layers and jets, influence of turbojet engine design parameters on noise output, and recent NACA investigations into noise-reduction devices for full-scale jet engines.

**Aircraft Instrumentation**—This subject, which has been missing from the past several annual meeting programs, will be a part of the forthcoming meeting. As a matter of fact, there will be two sessions on aircraft instrumentation. Papers are being presented on the newest instruments for astronomical navigation and on automatic flight control in modern air transportation. Instrument simplification, compass systems, and program flights are among the topics to be discussed in other papers scheduled for delivery at these two sessions.

**JATO for Aircraft**—Approximately ten papers will be read during the two sessions devoted to JATO for aircraft. These papers, which will touch upon both the commercial and military aspects of JATO, are to be presented by various representatives of rocket, aircraft, and propellant manufacturers, as well as certain air-line and military personnel. The papers will each be about 20 min. long. The JATO sessions are being cosponsored by the American Rocket Society and the Institute.

**Electronics in Aviation**—This year there will be two sessions on electronics in aviation. One of the sessions will be entitled "Electronic Aids to the Aircraft Industry"; the other one will be on "Aerial Surveying, Photographic and Electronic." Both sessions, scheduled for January 26, are given under the joint sponsorship of the Institute of Radio Engineers, the Radio Technical Commission for Aeronautics, and the IAS.

In the electronic aids session, it is planned to have four papers presented. These will cover the use of simulation in design synthesis as applied to a manned airplane, problems that can be solved in missile design through simulation, electronic simulators as training aids, and electronic analog equipment.

J. L. Atwood

The session on aerial surveying will include papers on the following topics: (1) a general paper that gives a broad introduction, the applications, and the economic aspects of aerial surveying; (2) problems of aircraft construction for magnetometer work; (3) effects of the systems approach on reconnaissance equipment design; and (4) requirements of military aircraft design for aerial photography.

**Other Sessions**—The remainder of the program for the Twenty-Third Annual Meeting will include sessions on aeroelasticity, aerodynamics, structures, aircraft design, flight propulsion, automatic control, air transport, rotating wing aircraft, and flight safety. The sessions on rotating wing and flight safety will be sponsored by the IAS in cooperation with the American Helicopter Society and with The Daniel and Florence Guggenheim Aviation Safety Center at Cornell University, respectively.

The IAS Annual Business Meeting will be held on Wednesday, January 26, at 5:00 p.m. Official written notice of this business meeting as well as the printed program containing full information on the forthcoming annual meeting will be in the hands of IAS members before the end of this year.

# CAI-IAS International Conference

***Canadian Aeronautical Institute Gets Off to Good Start. Program Featuring Nine Papers, Dinner, and Canadian Plant Tour Highly Successful.***

The recently activated Canadian Aeronautical Institute did itself proud in organizing and conducting its first big meeting. International in scope, this initial conference attracted a surprisingly large number of delegates from the United States and all parts of Canada. Nearly 500 people were accounted for at the dinner and technical sessions held at the Sheraton-Mount Royal Hotel in Montreal on October 14–15.

The five Canadian and four American papers, presented during three technical sessions, are as follows:

"The Role of Fluid Mechanics in Aeronautical Development"—Dr. G. N. Patterson, Director, Institute of Aerophysics, and Head, Dept. of Aero. Engrg., Univ. of Toronto.

"Flying Techniques with the Research Airplanes"—A. Scott Crossfield, Aeronautical Research Scientist, NACA High-Speed Flight Station, Edwards AFB.

"The Nature and Stiffness of Swept-Wing Deformations with Reference to the Prediction of Normal Modes and Frequencies"—Albert H. Hall, Assoc. Research Officer, National Aeronautical Establishment of Canada.

"The Orenda and the Future: Mechanical Design Considerations of Canada's First Production Turbo-Jet"—B. A. Avery, Asst. Chief Design Engineer, Gas Turbine Div., A. V. Roe Canada Ltd.

"Bases Unlimited"—Ernest G. Stout, Chief of Naval Aircraft Research, Convair Division of General Dynamics Corp.

"Production of an All-Weather Long-Range Jet Fighter"—R. K. Anderson, Asst. Industrial Engineering Manager, Aircraft Div., A. V. Roe Canada Ltd.

"Air Traffic Control and the Turbo-Jet Aircraft"—Charles W. Carmody, Chief, Operational Procedures Branch, Airways Operations Div., CAA.

"RCAF Training Operations"—W/C C. H. Mussels, C.O., RCAF, Central Flying School, Trenton, Canada.

"Design Aspects of the Boeing Model 707"—Kenneth C. Gordon, Boeing Airplane Co.

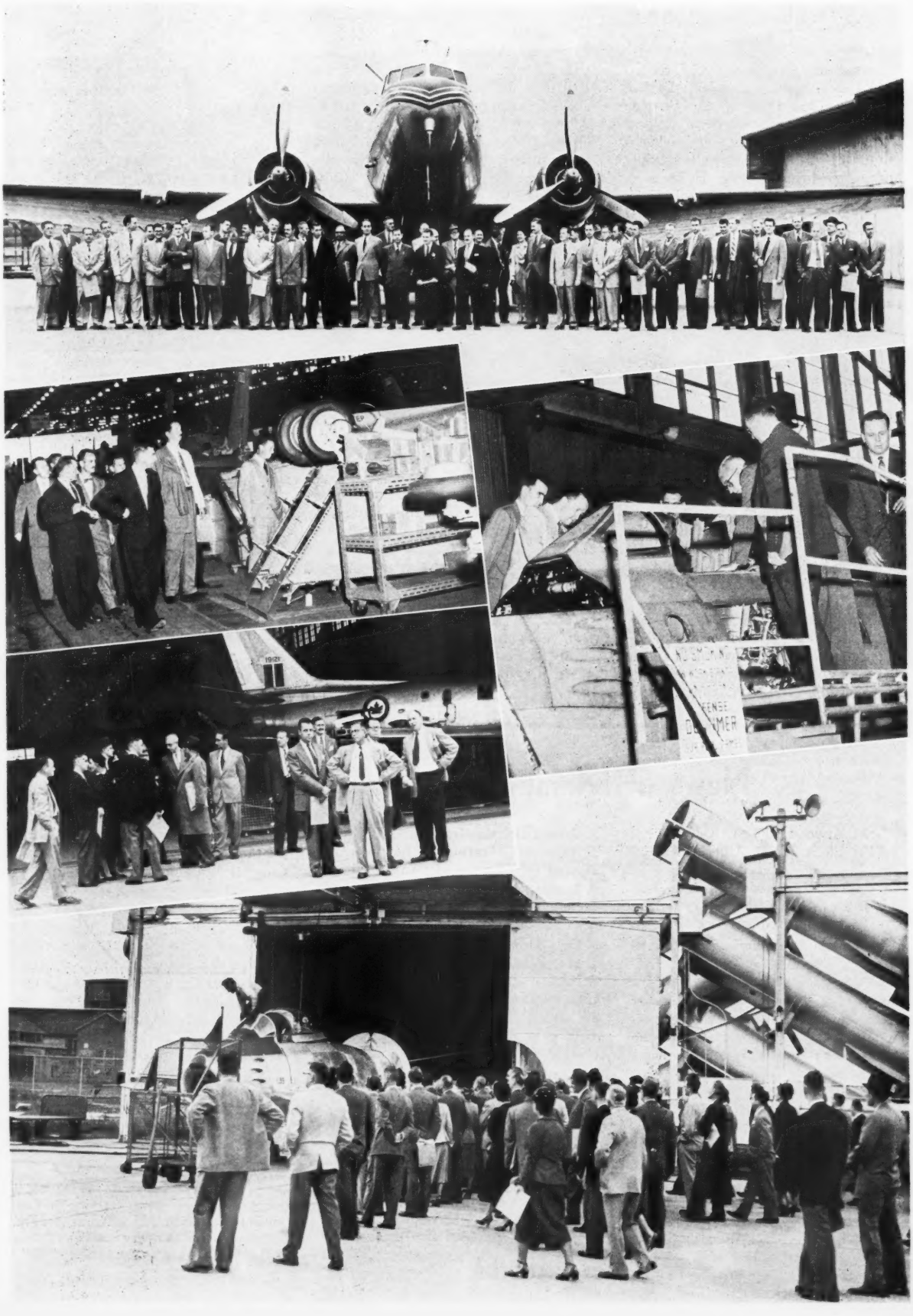
Chairmen for the three technical sessions were: T. E. Stephenson, Director, Aircraft Branch, Department of Defence Production, Canada; W. K. Ebel, Vice-President, Engineering, Canadair Limited; and G. R. McGregor, President, Trans-Canada Airlines.

It is the intention of the CAI to publish some of these papers in the Society's monthly *Log*. Several will appear in early issues of the REVIEW. Preprints of the majority of papers (as noted on p. 122, November issue) are still available through the IAS.

Hugh L. Dryden, principal speaker at the conference dinner on October 14, was introduced to an appreciative audience by CAI President John J. Green. Dr. Dryden's address appears as the Guest Editorial in this issue, p. 40. L. B. Richardson, Senior Vice-President of General Dynamics Corporation and a past president of the IAS, attended as official IAS representative at the dinner and conference.

As guests of Canadair Ltd., delegates were treated to a tour of the company's facilities, a luncheon, and flight demonstrations by a Canadair Orenda-powered F-86 and a T-33. Hosts on this occasion were W. K. Ebel, Engineering Vice-President, and E. B. Schaefer, Assistant Chief Engineer, who, together with members of their staffs, provided an interesting show—as indicated by pictures shown on the opposite page.

**CAI President John J. Green addressing the dinner audience.**



## IAS Members Elected SSA Officers

Lieutenant Colonel Floyd J. Sweet, USAF, MIAS, has been elected President for 1954–1955 of the Soaring Society of America, Inc. Colonel Sweet, a 1937 University of Michigan graduate, has been active in gliding and soaring since 1929. He is presently Assistant Chief, Aircraft Branch, Aeronautics Division, Directorate of Research and Development, Headquarters, USAF, Washington, D.C.

Other IAS members elected to official capacities in the SSA for 1954–1955 are: Dr. Wolfgang Klemperer, FIAS, Research Engineer, Douglas Aircraft Company, Inc.; Capt. Ralph S. Barnaby, USN (Ret.), FIAS, Chairman, Aeronautical Section, Electrical Engineering Division, Franklin Institute Laboratories for Research and Development; and Paul A. Schweizer, MIAS, Vice-President and General Manager, Schweizer Aircraft Corporation. Dr. Klemperer is the SSA Honorary Vice-President; Captain Barnaby is the SSA East Coast Vice-President; and Mr. Schweizer is the SSA Secretary.

The positions of SSA West Coast Vice-President and Treasurer for 1954–1955 are held by Theodore Nelson, of San Leandro, Calif., and E. J. Reeves, of Dallas, respectively.

## Necrology

### Eugene Gerhardt

Eugene Gerhardt, TMIAS, Designer, Chance Vought Aircraft, Incorporated, was killed on September 11 when the aircraft in which he was a passenger was involved in a mid-air collision and crashed near Arlington, Texas.

Born on August 1, 1897, in Goettingen, Germany, Mr. Gerhardt matriculated at the University of Leipzig in 1917. A philosophy major, he received his Ph.D. degree from Leipzig in November of 1921. He came to the United States some time later and in 1934 became a naturalized American citizen.

In 1948, Mr. Gerhardt went to work for the Fairchild Aircraft Division of Fairchild Engine and Airplane Corporation as a Layout Draftsman. Two years later, he became associated with Chance Vought.

Mr. Gerhardt had no close relatives.

# News of Members

▸ **J. L. Atwood** (F), IAS President and President, North American Aviation, Inc., was elected a Director of the Atomic Industrial Forum, Inc. This is an organization supported by industrial firms, educational institutions, and labor unions interested in using atomic energy for peaceful purposes.

▸ **Millard V. Barton** (AF), a member of the Technical Staff of The Ramo-Wooldridge Corporation's Guided Missile Research Division, is currently on leave of absence from the University of Texas. At Texas, he has been Chairman of the Department of Engineering Mechanics and Research Engineer at the Defense Research Laboratory.

▸ **Harold M. DeGroff** (M), is Acting Head of the School of Aeronautics, Purdue University, during the absence of Dr. Milton U. Clauser, MIAS (see photo on this page). Mr. DeGroff was an Associate Professor in the school's Aeronautics Department.

▸ **Frederick C. Durant, III** (AF), Engineering Consultant, has been re-elected President of the International Astronautical Federation. The IAF membership is comprised of rocket and astronautical societies of 17 countries.

▸ **Dr. Donnell W. Dutton** (AF), Director and Professor, Guggenheim School of Aeronautics, Georgia Institute of Technology, is a Director of Winder Aircraft Corporation. Dr. Dutton is presently working on a new product for the company.

▸ **Frank A. McCann, Jr.** (AM) has been admitted as a general partner in the mechanical and electrical engineering firm of Stevens and Grow of 746 S. Alvarado St., Los Angeles 57. The company is now known as Stevens, Grow and McCann. Mr. McCann was formerly Contracts Administrator, Research and Development Laboratories, Rheem Manufacturing Company.

▸ **James L. Murray** (AF), was recently appointed Assistant to the President of The Garrett Corporation. Continuing as Engineering Representative for the corporation, Mr. Murray has also been assigned to report on long-range research and development projects and on new products for the AiResearch Manufacturing Divisions.

**Dr. Milton U. Clauser, MIAS, has been granted a year's leave of absence as Head of Purdue University's School of Aeronautics. Dr. Clauser is now Director of the Aeronautics and Structures Staff, Guided Missile Research Division, The Ramo-Wooldridge Corporation.**

▸ **Frank N. Piasecki** (F), Chairman of the Board, Piasecki Helicopter Corporation, was the recipient of the Tribute of Appreciation Award of the National Defense Transportation Association. This award was presented to Mr. Piasecki for his "outstanding contribution to defense transportation."

▸ **Hyman Serbin** (M), Professor of Aeronautical Engineering, Purdue University, has been given a year's leave of absence by Purdue in order to work for the Convair-San Diego Division of General Dynamics Corporation.

▸ **Dr. Homer J. Stewart** (AF), Professor of Aeronautics, California Institute of Technology, was honored by his alma mater, the University of Minnesota, at a dinner on October 15 which commemorated the twenty-fifth anniversary of the Department of Aeronautical Engineering. At the October 15 dinner, Dr. Stewart received the University of Minnesota Outstanding Achievement Award for former students of the University who have achieved high eminence and distinction.

### *Members on the Move*

**The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.**

**Robert M. Benson** (M), Vice-President in charge of the West Coast Division,

Gyromechanisms, Inc. Formerly, Chief Engineer, American Gyro Corporation.

**Dr. K. C. Black** (M), Head, Communications Engineering Department, Raytheon Manufacturing Company. Formerly, Business Manager, Polytechnic Research and Development Company, Inc.

**Donald H. Blose** (M), Assistant Project Engineer, Q-4 Project, Radioplane Company. Formerly, Project Control Engineer, Bombardment Missiles Division, Wright Air Development Center, Wright-Patterson AFB, Ohio.

**John J. Boericke, Jr.** (M), Head, Stainless Steel Department, Fleetwings Division, Kaiser Metal Products, Inc. Formerly, Project Manager, Fleetwings Division, Kaiser. (Kaiser's Fleetwings Division was until recently known as the Aircraft Division.)

**William O. Boschen** (AM), Director of Sales, AVIEN, Inc. Formerly, Eastern Regional Manager, Aeronautical Division, Minneapolis-Honeywell Regulator Company.

**Gibson A. Cederborg** (TM), Engineering Writer, Brown Instruments Division, Minneapolis-Honeywell Regulator Company. Formerly, Specifications Engineer, Aviation Gas Turbine Division, Westinghouse Electric Corporation.

**Norman A. Champness** (M), Research Electronics Engineer, Cornell Aeronautical Laboratory, Inc. Formerly, Electronics Engineer, Bell Aircraft Corporation.

**Sam Emer** (TM), with General Engineering Department, The Aluminum Company of Canada, Ltd. Formerly, Design Draftsman, A. V. Roe Canada Limited.

**Second Lieutenant John J. Gallagher** USAFR (TM), Extended Active Duty, USAFE. Formerly, College Trainee, Allison Division, General Motors Corporation.

**Lieutenant Commander John Huson, USNR** (M), Head, Guided Missiles Branch, Aviation Requirements, Office of Naval Research, Special Devices Center, Port Washington, N.Y. Formerly, Maintenance Officer, FASRON 103, NAS, Patuxent River, Md.

**Franklin H. Joseph** (AM), Policy and Planning Supervisor, Sperry Gyroscope Company, Division of The Sperry Corporation. Formerly, USAF Production Representative, Sperry Gyroscope.

**J. Nelson Kelly** (AM), Division General Manager, Aircraft Service Division, Lear, Incorporated. Formerly, Executive Vice-President, Boots Aircraft Nut Corporation.

**Allan M. McCaskill** (TM), Aerodynamicist, Santa Monica Division, Douglas Aircraft Company, Inc. Formerly, Research Assistant, Forrestal Research Center, Princeton University.

**James D. Redding** (AF), Assistant to the Chief Engineer, Aviation Gas Turbine Division, Westinghouse Electric Corporation. Formerly, Executive Director, Committee on Aeronautics, Research and Development Board, Department of Defense.

(*Continued on page 74*)

**Dr. Howard W. Barlow *(right)*, AFIAS, is greeted by Dr. C. Clement French, President, State College of Washington, as Dr. Barlow assumes his duties as Director of the Washington State Institute of Technology. Dr. Barlow, who succeeds Dr. William A. Pearl in this position, was formerly with the Agricultural and Mechanical College of Texas where he served as Dean of Engineering, Director of the Texas Engineering Experiment Station, and Director of the Engineering Extension Service.**

**Robert H. Davies, MIAS, has been appointed Vice-President in charge of Engineering for The Parker Appliance Company and its subsidiaries. Mr. Davies has been with Parker since 1939 and had been Engineering Manager for the firm since 1946.**

**Otto E. Kirchner, FIAS, has joined the Preliminary Design Unit of Boeing Airplane Company's Engineering Department and is conducting commercial aircraft studies. Mr. Kirchner was formerly Director of Operational Engineering for American Airlines, Inc.**

**Dr. David J. Peery, MIAS, is now Professor of Aeronautical Engineering at the University of Michigan. He had been associated with The Pennsylvania State University from 1942 until his recent resignation as Professor and Head of Penn State's Department of Aeronautical Engineering.**

# Guest Editorial

# Aeronautical Research and the Art of Airplane Design

By

Hugh L. Dryden

*Director*

*National Advisory Committee for Aeronautics*

Dinner address presented at the joint meeting of the Canadian Aeronautical Institute and the Institute of the Aeronautical Sciences, Montreal, Canada, October 14, 1954.

TWENTY-TWO YEARS AGO, the Institute of the Aeronautical Sciences was incorporated for the purpose, among others, of advancing the art and science of aeronautics. At the Founders' Day Meeting in January of the next year E. P. Warner gave a brief talk on "The Application of Science to Design." According to the printed abstract, he dealt with the status of airplane design and with the question of the extent to which it could be made rigorously subordinate to scientific rules. He asserted that while practical airplane design was an art, pure science had been steadily encroaching upon the ground of "engineering judgment." He suggested that it would be a good thing for every engineering staff to have at least one member whose sole duty it would be to keep abreast of advances in aerodynamic theory and in the theory of structures. This individual should constantly press their possible practical applications upon the attention of his superiors on the staff.

General James H. Doolittle had a few months before returned the landplane speed record to the United States by flying his racing airplane at 296.287 m.p.h. Our technical progress since then may be measured by the events of last December when Major Charles Yeager attained a speed of about 1,650 m.p.h. in a research airplane. During the past year several tactical military airplanes demonstrated their ability to fly faster than sound in level flight. This remarkable increase in performance has been accomplished by the "steady encroachment of science upon the ground of engineering judgment." But I believe that there is still an art as well as a science of aeronautics. I wish to discuss briefly the interplay of scientific research and the art of design in aeronautical progress.

The essential difference in outlook between the research scientist and the designer was brought forcibly to my attention by a visit from Sir William Farren after he had made the transformation from research director to airplane designer.

"You know," he said to me, "I envy you research fellows. I come to tell you my troubles. My prototype airplane has a tricky control characteristic and shakes a bit too much, and I ask you what I should do. You think a bit, look at your curves, and manipulate your slide rule, and very confidently say to

me, 'If I were you, I would raise the horizontal tail 3 ft., increase the size of the vertical tail 10 per cent, and make the wing root fairing larger.' I thank you, return home, sweat out the modifications for 6 months, and anxiously await the result of the first test flight. My test pilot tells me that there is no improvement. I report this to you somewhat plaintively a year after my first visit. You tell me, 'I was afraid that those changes might not be effective, especially after we got some more test data after your visit. Too bad. If I were you, I'd move the tail 2 ft. lower than its original position.' What a racket. I can do that kind of guessing myself. The designer's life is a sorry one. I should never have left the Royal Aircraft Establishment." (With apologies to Sir William Farren for inaccurate reporting.)

Research advances knowledge by isolation of limited aspects of development problems which are analyzed by specialists in specific fields. The designer of an airplane or missile must solve *all* of the many problems in a single integrated prototype. Design is still an art practiced by individuals or groups of individuals in a design team. They must have general knowledge of many fields and the ability to synthesize information from many sources.

A useful airplane, like any other accomplishment of the human race, is preceded by creative activity in the invisible world of some human mind. The pathway from vision to accomplishment is sometimes long and arduous. For a number of years following the first successful flight it was possible for any individual to learn and know all there was to be known about aeronautics and aircraft design. If equipped with the requisite powers of vision, he might become a successful designer. The situation soon changed. Today it is extremely difficult to discover *the* designer of one of our modern airplanes. It is the product of a large organization of many specialists of many types,

**Dr. Dryden addressing CAI-IAS dinner group in Montreal.**

of a team. No member of the team has complete knowledge of the final product in all its detail. When you examine this modern air liner you do indeed wonder how any one man could have invented or designed it. Of course, no one man did or could. Its development rests on the contributions of many men in the past and of many men now living.

The vision of the designer is guided today not only by the experience and accomplishments of the past but also by the specialized and somewhat artificial type of experience known as scientific research. Modern science seeks to know and understand the laws of Nature: how air flows around bodies; what forces, pressures, and loads are exerted on bodies moving through the air; and how materials and structures behave under load. Such knowledge is the secure foundation on which all engineering accomplishment rests.

The feeding of the results of the experiences of the research worker into the mind of the engineer does not, however, make him a creative designer. The distillation of the discoveries of other men into an engineering handbook may provide sufficient basis for the training of engineers in some fields. But in aeronautics economy of materials and refinement of design are of great importance. Handbook engineers are of no value in aeronautical development today. Similarly, mere training in the knowledge and techniques of the aeronautical sciences will not make a good member of an aircraft design team. The art of inventive application must also be mastered, the art of finding new means to old ends, skill in finding new combinations of old elements. Problems must be met not only with correct scientific and technical knowledge but also with ingenuity. Creative activity within the mind of the aircraft designer is the first step along the pathway toward the practical realization of a successful airplane.

The next step is to send out exploring parties, to make forays to verify or modify the intended course. This is the activity of applied research. The questions are now asked of Nature. You recall Boss Kettering's approach of asking the diesel engine rather than a consulting engineer whether a given design of piston was good or not. The theoretical and conceptual ideas must be given the acid test of actual trial. If the theory proves wrong, if one approach does not make progress toward the goal, the intelligent engineer will seek a new theory or a new approach. In aeronautical development we find need for a great deal of applied research. Some is of a very specific nature directed to limited objectives. Some is of a very general nature directed to broad objectives. The result of all this activity is to establish confidence that the vision is a realizable one, that the *foreseen* problems can be solved. The unforeseen problems are another and later story.

The scene now reverts to the immaterial sphere of the mind. The problem now is to sharpen the vision to an integrated and coordinated design. Necessary compromises between conflicting requirements must be made. The solution must be consistent with demonstrated possibilities of achievement. The designer is a creative artist like the architect who, with a given site on a rocky hillside, a given family with certain living habits and needs, and a certain supply of available materials, plans a structure that most harmoniously meets the given conditions. Or, the designer is like the composer of a great symphony who knows the characteristics and capabilities of all of the different instruments and must write the score for all. The result is to be a unified and integrated composition. The success or failure is in the composer's hands and is decided before the orchestra plays a single note.

The symphony orchestra conductor now takes over from the composer, the builder from the architect, the production engineers and artisans from the airplane designer. Their job is to make the vision come true, to turn notes into music, plans into houses, acres of blueprints into a structure of aluminum, steel, and plastic—an airplane. At every step the same cycle of mental-physical activity is repeated. Each accomplishment is preconceived in the mind of man, and the more creative, inventive, experienced, and intelligent the man who conceives and plans, the more advanced and the more suitable to its purpose is the resulting product.

Now come the unforeseen problems as the user takes over. The new airplane is not born to be set on a pedestal and admired for its beauty, for the complexity of its construction, or for its cost. It was made to serve a purpose; it is a tool to accomplish the purposes of man in transporting him and his possessions or in fighting his enemies. The infant airplane moves out of the factory to the flying field. It is rained on, hailed on, frozen and scorched, and pounded by gusts and hard landings. The process of evaluation and further development to overcome shortcomings begins. This is the life cycle of a new airplane.

During the life of the Institute of the Aeronautical Sciences we have seen aircraft design expand from the solo effort of the inventor to the symphony of the team. It seems to me that we are in an era in which even this latter concept is inadequate. After all, the score of the symphony can be broken down into separate scores for each instrument. A coordination is necessary as regards time, melody, and harmony, but this can readily be accomplished because the details of the score for each instrument can be worked out—once the general structure of the composition is given—with little interference or interaction.

Prior to World War II, the design problems of an airplane could be readily broken down into aerodynamic, power-plant, structural, electrical, hydraulic, etc. Each group could work out the optimum solution from its own specialized point of view with comparatively little interference. The most necessary coordination was a purely dimensional one. Space must be available as required. Mating parts must fit and

operate without mechanical interference. There were, of course, a few problems of a different nature, such as the effect of the propeller slipstream on the stability and control of the airplane. This problem required consideration and optimization of the mutual effects by the propeller and stability groups. Similarly, the drag associated with cooling required joint study by the power-plant and aerodynamics groups. As speeds increased, the aerodynamicist began to complain to the many crude excrescences demanded by the electronics group for radio and radar antennas. As structural design was refined, the mutual effects of aerodynamic loads on structural deflection and of structural deflection on aerodynamic loads introduced borderline problems of flutter and aeroelasticity. Modern powerplants swallow so much air that the separation of thrust from drag becomes almost a matter of definition. The interaction between power plant and flow around the air frame is so great that experiments on the whole configuration, with operation of the power plant present or simulated, become almost indispensable. High speeds show up the limitations of the human body as a servomechanism for responding to stimuli, and a whole new science of automatic control of aircraft is being born.

In all of these cases the mutual interactions are large, and functional coordination is required. New methods for systems analysis must be devised. Complexities of a new type are introduced. The problem is far different from one that involves merely the pyramiding of a large number of similar elements, as one does in building a large apartment house as compared with building a single house. There, the only difference is in the number of bricks and workmen required. In the past the building of a large aircraft differed from that of building a small one only in that many more people were required to do the detail design of many more joints and pieces. The building of a modern high-speed aircraft or missile today requires a new concept of team activity and functional coordination, and a team consisting of more kinds of specialists with knowledge of more scientific fields. The apparent slowness of guided-missile development stems from these new requirements. The teams had to be assembled and had to learn to work together. They had to learn the nature of the intricate problems and methods for their solution by actual experience. They had to develop methods of systems analysis and to overcome unforeseen problems.

The development of the art of airplane and missile design to its present state would have been impossible without the accompanying advance in scientific research and the utilization of the results by the designer. Research has also progressed from the unrelated investigations of a comparatively few individuals on subjects that interested them. We now have the organized effort of large groups on programs whose goals are set by the joint thinking of university scientists, research staff, aircraft designers, and aircraft users. It is the collaboration of scientist, designer, and user which has made present-day aeronautical research so fruitful and permitted such a rapid rate of progress.

It has become necessary to achieve a more satisfactory integrations of the efforts of research scientists and designers than that pictured in the Farren story. We who are engaged in research are pleased by the manner in which our collaboration with the design teams responsible for many current prototype aircraft is being recognized by the members of those design teams as an important element in the success of their new aircraft. And today the performance of the new prototypes underlines the accuracy of predictions drawn from the wind-tunnel and other research data. Conversely, today's research workers have a keener understanding of the designer's tasks. Perhaps, also, they have a more intimate awareness of his responsibilities in the aircraft development process.

There is no sign of a limit to aircraft development or to the ever-widening horizons of aeronautical research. The sonic barrier has been found to be less formidable than anticipated. Before us lie the problems of still higher speeds and altitudes and of aerodynamic heating, complex structural problems, and difficult stability and control problems in the thin upper air. The same collaboration of scientist and designer which has multiplied the speed more than 5 times in 22 years will solve these new problems.

In conclusion, there is still both art and science in aeronautics. The design of aircraft will never be "rigorously subordinate to scientific rules." But without a steady increase in scientific knowledge the art of aircraft design would become stagnant; supported by a vigorous scientific activity in aeronautical research, the art of design will flourish.

Actual and possible accomplishments will expand, and visions, hitherto unrealizable, will become practical engineering projects.

# Wing Design for Practical High-Speed Aircraft

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IT IS A GRATIFYING EXPERIENCE for airplane designers to witness the continuing manufacture of their designs or the improved development of those designs for many, many years. At Boeing we saw the 1935 design of our model 299 continue in the B-17 family and in the original Stratoliner family for a period of ten years. We saw the 1940 design of our XB-29 grow through the B-29 production series to the B-50, its sister-transport the C-97, and the Stratocruiser family. The C-97 is still in production 14 years after the initial designs of its major components were laid down. The Constellation and the Douglas DC-6 and DC-7 airplanes grew from initial designs of this same period. Many hundreds of airplanes of these types have been built, and the results of these programs have been extremely satisfying to the military and commercial users of these products, to the management, and to the stockholders of the companies that developed and built them. If the designers at Lockheed or Douglas envisioned for their initial efforts the kind of design life that these airplanes have experienced, their abilities at true prophecy were, to say the least, far better than those of this individual at Boeing. Through the years the man-hour cost of production has come down the learning curve, and unit tooling costs per airplane have come down because of amortization over greater numbers of airplanes produced. The desire of management to stretch the use of these airplanes as far as possible is understandable.

But to the designer this happy experience in our past presents a challenge, since the pattern has been established and it is only logical to expect that we shall repeat this performance in the useful manufacturing life span of any new article we lay down today. We must review the factors that have enabled us to stretch our old designs this far, and here do not let me imply that these example airplanes have reached the end of their respective life spans today. They have not; there is a lot of stretch left in them yet. It appears that, like old soldiers, they will never die, and that they will yield their place as the world's foremost transport airplanes only to the newcomer that can beat them out fair and square in a battle of performance and economics. Any such newcomer must have considerable life expectancy if it is to win.

The factor that has given these designs their long life spans has been continuous improvement in their performance and load-carrying abilities. Higher and higher take-off weights have been demanded to accommodate greater pay load and fuel for increased range at increased cruising power. Higher take-off powers and increased runway lengths have made these weight increases possible. The B-29 family, including the C-97 and Stratocruiser, has increased in take-off weight at a rate of 5 per cent per year and is still growing. The DC-4 family started at 52,000 lbs. in 1942 and has grown to 122,000 lbs., or maybe more, today; that is a rate of 11 or 12 per cent per year. My first knowledge of the Constellation was at 82,000 lbs. in 1943, and now it is up to 150,000 lbs. in a turboprop version some time this year; that is 7 per cent per year. This growth has not been painless, and much structural redesign has been necessary along the way.

The substitution of higher strength materials, the addition of relieving fuel weights farther outboard on the wings, reduction in arbitrary maneuver and landing-load factors, and considerable, sharp pencil work have been used to reduce the impact of these changes on the physical article and hence on the tools and jigs and on the shop experience.

In no case during the initial design periods of these airplanes did we try deliberately to provide for the growth we have experienced. When we were designing the XB-29 wing for a 105,000-lb. bomber, we would have predicted that the use of this wing on a 175,000 lb. C-97 was utterly impossible, but it has happened. Had we designed that wing initially for the 175,000-lb. airplane, the result in terms of wing weight would have been disastrous to the B-29.

In a discussion of the problems of tooling, fabricating, and assembling the components of the kind of airplanes we are designing today one fact will surely stand out: Regardless of how well the job is done, the tools and fixtures for manufacturing and assembling these modern airplanes are not cheap. Considerable investments of dollars and effort are necessary to bring the airplane from the drawing board to the flying field. Changes of the relative magnitude of those we have experienced in the past will be much more difficult and expensive to accomplish in our future product. Thus it appears that if, on the one hand, we have an almost certain expectancy that strength increases are to be required and, on the other, the certainty that changes will be extremely costly, then we dare not leave this growth to chance, but must plan for it and plan carefully and wisely to avoid weight penalties in the initial airplane which might kill the program before it is born.

The designer must recognize those elements of the aircraft structure in which the greatest outlay of dollars for manufacturing tools and jigs occurs and

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strive to design in such a way that strength changes can be made without change to these basic elements. If changes to these basic elements are inevitable, they must be planned from the outset and coordinated with the tool designer and process planner to ensure the best possible chance of improving the airplane at minimum cost. Recognition of these probable future requirements can have a profound effect upon the selection of the basic structure to be used and upon the techniques chosen to obtain it.

It is here that the nature of the aircraft problem conflicts with the automatic or mass-production philosophy. Many techniques are available to the aircraft designer to simplify the job of assembling aircraft, usually by eliminating the job of joining multiple parts by making them integral with each other. This process promises a cheaper product in terms of assembly man-hours, at a higher initial tooling or developmental cost. The cost implications of this are obvious: Small quantities of parts are generally cheaper if made largely by hand; as the number of airplanes to be built increases the degree of mechanization and justifiable tool cost increases.

Let us take several examples to determine the effect of these considerations on the type of structure we should use. Consider, first, a wing panel adjacent to the body of a tricycle-gear type of airplane with the landing gear supported by the wing. Such a panel must carry local air loads, serve as the wall of an integral fuel tank, and carry local fuel pressure loads, primary wing bending moments, torsions due to the landing gear loads, torsions due to air loads, and dead weights such as engine nacelles mounted outboard. Available to the designer are a number of methods for developing this panel:

(1) Conventional sheet and stringer construction with stringers riveted to the skin. Variation in load along the span or along the chord can be accommodated by tapering the skin in thickness by rolling or by machining, or the stringer areas can be varied by machining. Variations of this basic scheme are found in constructions in which the stringers are welded or bonded to the skin and in constructions where corrugations replace the stiffener members.

(2) Extruded skin and integral stiffener construction in which the skin and stiffeners are produced as one homogeneous part. Area variation to accommodate varying load can be obtained by machining on the outside or between stiffeners or by machining the stiffeners.

(3) Machined skin and integral stiffeners in which the skin and stiffeners are machined from plate stock by removing the unwanted material from between the stiffeners. The stiffener depths and shapes available by this method appear to be somewhat limited, but the variations in skin thickness or in stiffener direction, and even intersecting stiffener arrangements, are infinite.

The designer selecting from these basic structural types will find that at some values of panel loading in pounds per inch one or the other of these schemes will show a definite, though probably small, weight superiority over the other methods because of its ability to develop a higher column or buckling allowable stress. The methods producing integral stiffeners will generally produce the highest allowables at low to medium values of load per inch, but, as the load per inch increases, the method employing separate stiffeners riveted to the skin is equal in structural efficiency to the other methods. For equal values of load per inch it generally is possible to employ greater rib spacing with the riveted stiffener arrangements because of greater freedom to employ deep section stiffeners. For the size and type of airplane with which we at Boeing have had reason to compare these several methods of construction, we have concluded that on a structural efficiency basis they are at a stand-off, that with comparable effort in detail design they will yield comparable structural weights. The choice, then, must be made on other bases than weight.

The riveted skin and stiffener type of construction has the advantage of complete familiarity gained through its use on many projects in the past. The skin thickness variations obtained through roll tapering or skin milling are most easily accomplished in this configuration. Further area change control is easily accomplished through stiffener milling and by providing a variable stiffener spacing. Contour control by use of prerolled skins or simply by bending the skins to contour on installation is quite easily accomplished since the stiffeners are not attached to the skin at the time of forming. The tooling for this construction consists generally of panel jigs in which top and bottom panel subassemblies are built up of relatively inexpensive parts, and with the exception of machine-tapered or sculptured skins, of parts that are produced on more or less standard machine tools. This construction lends itself most conveniently to strength changes that may be desired during the life of the basic design. The principal disadvantage of this construction is the problem of driving thousands of rivets. In one of our current designs more than 13,000 rivets are necessary in a single panel. These are in several sizes and lengths and must vary even in material. The cost of locating and preparing holes and of inserting and driving these thousands of rivets is a substantial one, and on airplanes with integral fuel tanks the inspection and rework process to ensure sealing is a direct function of the number of rivets.

The rivet problem, though susceptible to considerable reduction through use of automatic hole preparing and riveting equipment, is probably the biggest incentive for considering the other types of construction discussed. Since most of the rivets are needed to attach stringers to skin, an obvious solution is to make the stringer integral with the skin in the first place. The earliest approach to accomplishing this was through the use of extruded, integrally stiffened sheet. Excellent stiffener shapes and skin-stiffener relationships

are attainable. The principal difficulties with this construction result from inability as yet to produce adequate widths and the problems of straightening and of contour control, though the shot peening approach to the contour problem holds considerable promise. Details may present difficulties in local areas where gage increases in the skin are desirable to allow for holes for fuel fillers, boost pumps, etc. However, when you reflect for a moment on some of the clever things that have been accomplished in the past by subsequent forging and machining operations on extruded materials, it hardly seems probable that this difficulty will bother us for long.

The second approach to the integrally stiffened skin construction is that of machining out the unwanted material from a slab whose cross section initially was thick enough to enclose the stiffener depth as well as the skin thickness. Rolling-mill capacity is adequate to produce plate of dimensions suitable for any application we have investigated. Generally, the size of the individual part is limited by heat-treat facilities and by the dimensions of the milling machine upon which the work is to be done. It is here, in the development of the machine to perform the milling operation of removing the unwanted material, that we see the greatest objection to this construction, though it presents the same problems of contour forming found in the extruded skin and integral stiffener arrangement. H. V. Schwalenberg,* of North American Aviation, Inc., explains how his company has accomplished some of these items on airplane components of fighter size. From that discussion I am confident you will agree that this method shows its advantage resulting from reduced man-hours per panel only when the production quantities and rates are quite high.

A significant consideration in selecting the construction arrangement to be used is rate of production as well as total quantity predicted. If the anticipated rate is low enough to require two to four years to produce the total quantity envisioned, then almost certainly engine improvements will make a weight increase possible with an attendant increase in strength desired. Thus a construction having a break-even point of, say, 300 airplanes may never break even in a run of 500 airplanes if the cost of model changes along the way eats up its margin of superiority.

As a second example problem, let us consider a forged member, say a body-frame member at the point of wing-to-body connection—so chosen because here any change in pay-load weight would probably change the load carried by this member. The available means of fabrication are:

(1) Machine from block, using Keller-type equipment and milling tools.

(2) Machine from rough forgings, in much the same manner as for the first machining method mentioned except that less material need be removed.

(3) Die forgings with machine finishing of attachment points, machining to remove excess material resulting from errors of die closure or mismatching of dies or material which is inevitably trapped because of inability to face all surface cavities normal to the parting plane, and machining to remove material that is sometimes forced to a structurally disadvantageous location by forging draft requirements.

This group includes die forgings all the way from drop-hammer types to press forgings made on presses of sufficient capacity to maintain die-closure tolerances and mismatch tolerances of low enough magnitude to make much of the machine work for weight control unneccessary. These latter forgings are commonly referred to as "precision forgings."

(4) Low draft or zero draft precision forgings, in which it is possible to take a forged part directly to the airplane structure and install it merely by boring holes for attachment. Of course, this is attainable only in some special cases when it is possible to avoid the need for undercuts or cavities not normal to the parting plane.

These forging types have been listed in order of increasing forge-tool costs and decreasing labor cost. Generally the use of the parts machined from block are economical only for especially simple parts in small quantities. Frequently this process entails considerable weight penalties because the material improvement characteristics of forging metal flow have not occurred.

The second practice of machining almost all over the finished part from a rough forging is economical only in very small quantities or in some cases where the resulting part is so complex as to be unsuitable for complete forging treatment.

In the third category, though die costs are high, it is frequently found that the machine-finished die forging process produces the cheapest part in as few as 15 or 20 parts even though quite close tolerances are held in the forgings.

The fourth or zero draft category has not as yet been used extensively in medium to large size parts, and the technique is still somewhat uncertain for the production of large forgings. Indications are that the break-even point for these parts, as compared with machine-finished die forgings, may be in the range of 500 to 1,000 parts, suggesting that their use is probably confined to multiple-use parts and to parts that would not change shape because of minor model changes or changes in strength which may be required every few years.

The body-frame member we were considering would most probably be machined from a close-tolerance or precision die forging unless the quantity and rate of production were quite high, in which case a zero draft precision forging might be found feasible.

Here, as in the case of the wing panel we were examining a little earlier, we find that the selection of structural type is inextricably involved in the quantity

(*Continued on page 58*)

* Schwalenberg, H. V., "Fabrication Aspects of Large Structural Components," AERONAUTICAL ENGINEERING REVIEW, Vol. 13, No. 11, pp. 63–66, November, 1954.

# Designing the Cockpit for High-Speed Flight

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BY CONCENTRATING our research and development efforts on air frames, power plants, and air-borne electronics since World War II, spectacular advances have been made in aircraft performance. With these advances have come serious human problems associated with the operation of high-performance aircraft. In addition to the new physiological problems, it is becoming increasingly difficult to train pilots to operate our new high-speed airplanes with even marginal safety and operational effectiveness.

In the past we were always able to make reasonably effective use of the airplanes we built by selecting only the most gifted as air-crew members and then submitting them to a few months of highly specialized training. This has been an expensive solution to the problem, but it saved us in World War II and kept our losses within bounds in Korea.

With the airplanes we are now building, however, selection and training alone can no longer solve the problem. Now as the speed of flight increases, even our most highly selected and trained pilots have difficulty making the discriminations, decisions, and control manipulations required to operate our current high-performance aircraft safely and effectively under all conditions of flight. One need only look into the cockpit of any of our modern airplanes to discover the reason for this.

No competent aircraft engineer would consider using a B-17 type of wing on a B-47 or an F-51 engine to push an F-86. And yet all of our high-performance aircraft have cockpits that look almost like World War II cockpits, only more so. The same flight instruments that were of marginal utility at low subsonic speeds are now being used at transonic and supersonic speeds for making split-second decisions and performing flight maneuvers requiring great precision and speed of response. A number of new instruments have been added to the old ones, but in general they have only made matters worse because a person can no longer attend to all of them. The three basic aircraft controls—stick, rudder, and throttle—and the relationships they bear to aircraft response have not changed since the early days of aviation, even though they are notoriously ill-suited to human operation.

It was recently asserted by a high-ranking officer that not over 25 per cent of our Air Force pilots can be trusted to fly one of the Air Force's currently operational aircraft. Such a statement should not be interpreted as a criticism of Air Force pilots but rather as an indictment of the World War II cockpits in our modern high-performance airplanes. In any case, it appears that relatively few pilots can be trained to operate our new airplanes in a manner that takes full advantage of the performance potential we are presently building into them.

Even if it were possible to train a relatively small number of pilots to operate our new airplanes effectively, our problem would still be unsolved because such training would take more time than we can count on having in this atomic age. We dare not continue to take the risk of waiting 2 or 3 years for each new aircraft type to become effective after it has been put into large-scale operation.

Also, the fact is generally overlooked that the young men with the highest aptitude for learning to operate the airplanes we are now building are the very ones who would also make the best doctors, scientists, engineers, administrators, military leaders, and teachers if given training and experience in these fields. Young men smart enough to learn to operate our new airplanes are also smart enough to realize that they can succeed in some safer and equally rewarding profession, and consequently it is becoming increasingly difficult to recruit properly qualified pilot and air-crew trainees.

If the problem of making effective use of high-performance airplanes cannot be solved by selection and training, then what are the alternative solutions?

It is frequently proposed that the problem of utilizing high-performance aircraft can be solved only by taking men out of them and controlling them either remotely or automatically. Even if the state of the art would allow this, it would not solve the human problem; it would simply transfer it from the air to the ground and change the nature of the problem somewhat.

While it appears practical and advantageous to control airplanes either remotely or automatically in certain limited applications, there is little doubt that we shall have men in most of our high-performance airplanes for many years to come—perceiving flight situations on the spot as they occur and making and executing flight-control decisions as they become necessary.

We shall have men in most of our airplanes because men are capable of complex pattern discrimination and perceptual constancy, that mysterious ability that enables us, for example, to see round things as round and square things as square, even though we view them obliquely. We shall have men in our airplanes because they can respond appropriately to so many different kinds of inputs, because they have such an immense long-term storage capacity from which they can quickly select a program appropriate to the immediate situa-

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* Member of the Technical Staff.

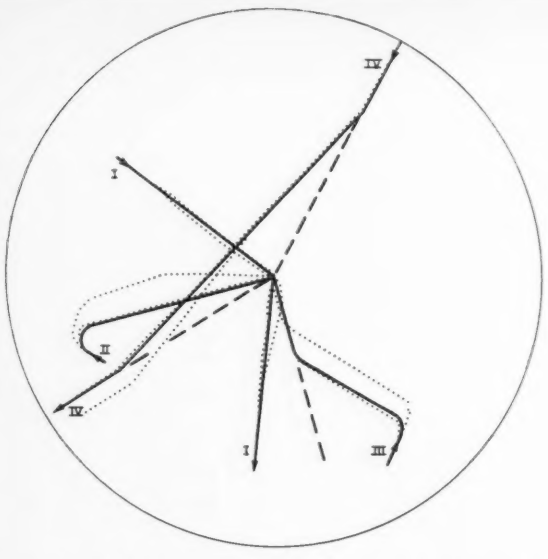


**Figure 1. Flight path recordings of the best and worst solutions to four terminal area navigation problems flown by instrument pilots using an outside-in pictorial navigation display.**

tion, because men can change their own transfer functions, because they contain the equivalent of approximately nine billion binary decision elements, and because men are relatively immune to jamming, are reasonably reliable, and relatively easy to maintain. Instead of taking the men out of our airplanes, we must take maximum advantage of these marvelous abilities possessed by all normal people.

The challenge to the aircraft industry—and the solution to one of its most pressing problems—is to design high-performance aircraft so that they can be operated safely and effectively by any normal person after a very brief period of training. This sounds like a big order, and it is. But it is not as big or expensive as some that have already been filled by the industry, and it could conceivably be delivered in time for some of the airplanes that are presently being developed. The obstacles are for the most part emotional rather than technical, although there are some challenging technical problems.

The technical problems will require a rather modest amount of imaginative and properly oriented experimental research leading to the development of (a) cockpit displays that will enable any normal person to interpret the flight situation at a glance and make appropriate decisions quickly and confidently under all weather conditions, (b) controls that will enable any normal person to execute his decisions quickly and accurately with a minimum of effort and attention, and (c) automatic equipment capable of performing certain functions that human beings cannot perform too well, such as integrating and differentiating, translating coordinates, performing routine numerical calculations, monitoring the operation of the aircraft, and executing routine programs requested by the pilot.

The amount of research necessary before these developments could be undertaken would be considerably less expensive than the research that has been done during the last few years on air frames, power plants, or electronic devices. It would cost only a fraction of the amount that is spent annually on pilot and crew training. This is true because the research that has already been done in this area has provided a fairly good indication of what the basic problems are and what questions must yet be answered experimentally in order to solve these problems.

The answers that we need must be of a sufficiently general nature to apply to all types of airplanes and all types of missions and yet sufficiently specific and detailed to enable the individual system engineer to apply them to a particular system.

I shall not attempt to outline such a research program at this time but shall present a few of the basic problems and the nature and order of the benefits we may expect from their experimental investigation.

Let us consider the basic task of directing an airplane through space, excluding from consideration the problems associated with the mechanical operation of the aircraft itself or the problems associated with any special tasks required in performing a particular mission.

In designing controls and visual displays to be used in directing an airplane through space, three fundamental decisions must always be made. Two of the decisions involve only the displays, while the third involves both the displays and controls. Let us consider the display decisions first.

Since any visual display of spatial flight information presents one or more aspects of aircraft performance in relation to the outside world, each display presents at least two indices.* At least one of these indices always represents aircraft performance, and at least one represents some aspect of the outside world.

Since this is true, decisions must be made concerning (1) the configuration of the indices and (2) the movement of the indices.

These may sound like simple or even trivial decisions, but they most certainly are not. The decision concerning the configuration of the indices encompasses a host of subsidiary questions: whether closely related aspects of the outside world are to be presented in a common coordinate system or scattered around in discrete, unrelated frames of reference; whether the display shall be "pictorial" or "symbolic"; whether certain information is to be presented as a direct indication of actual aircraft performance or as an error signal representing only the difference between actual and desired performance.

The question of the movement of the indices is equally important. Since at least one of the indices

* One of the indices may be implicit, as in the case of a display presenting only a simple numerical indication.

must be capable of moving if any information is to be presented, a decision must be made as to whether the primary moving index is to represent the aircraft's performance or the outside world.* This is the question of inside-out vs. outside-in, or aircraft coordinates vs. earth coordinates, or moving card vs. moving pointer.

Perhaps the most emotionally controversial theory in aircraft instrument design refers to this question. It is known as the "principle of the moving part" which asserts that the part of the display that moves should represent aircraft performance rather than the outside world.

The experimental evidence is not yet sufficient to determine the generality of this principle, but in every case in which it has been put to critical comparative test it has been found to hold true.

Two examples will now be shown to indicate the importance of the two basic design decisions that have just been discussed and the improvement in pilot performance that can be expected when the proper choice is made.

The first example presents a comparison of the performances of a group of instrument pilots flying terminal area navigation problems in a Link trainer using two different VOR navigation displays. The problems are typical of those encountered in an air traffic control situation.

One of the displays was conventional, consisting of a course selector, a cross pointer with an ambiguity indicator, and a compass. The other was an experimental map-type navigation display, smaller but basically similar to the Arma Pictorial Computer. This display presented all of the pertinently related information in a common coordinate system and followed the principle of the moving part. The conventional display presented related bits of information in different indicators, violated the principle of the moving part, and occupied slightly more panel space.

The results (see Figs. 1 and 2) strongly suggest that the configuration of navigation displays at least should be such that all pertinently related information is presented in a common coordinate system, thus enabling the pilot to perceive spatial relationships directly. He should not be required to form a mental map or picture of these spatial relationships by correlating discrete indications. When these relationships are presented to him directly, he can make correct course-of-action decisions quickly and execute them accurately. It should be noted that this method of data presentation leads not to more instruments but to a small number of integrated displays requiring less panel space and less weight.

The second example involves the principle of the moving part almost exclusively. It is a comparison

* Of course it is possible for a display to have additional moving indices representing, for example, other aircraft also moving in relation to the outside world.

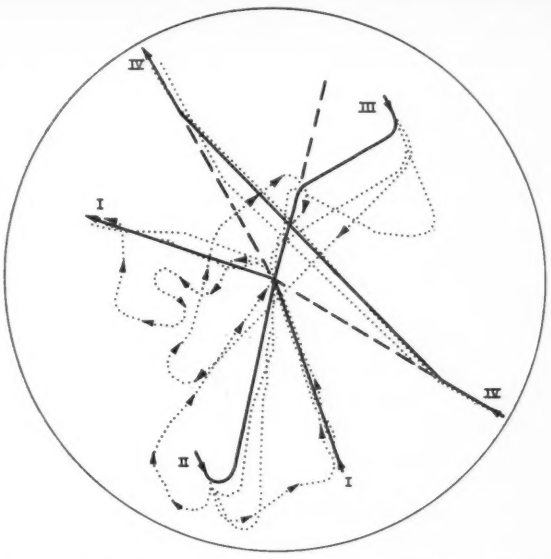


**Figure 2. Flight path recordings of the best and worst solutions to four terminal area navigation problems flown by instrument pilots using an inside-out cross pointer and course selector display.**

of the learning curves for two groups of pilots, one group using a conventional inside-out, director-type steering display that also presented aircraft attitude, the other group using the same display modified to present the same information in an outside-in manner. Thus the conventional display represented the horizon as moving in relation to a fixed airplane, while the experimental display represented the airplane as moving in relation to a fixed horizon. This experiment was also conducted in a simulator. Once again let us compare the results. (See Fig. 3.)

Several things should be noted concerning these results. Not only is there a large difference in the overall performances with the two displays but also an immensely important difference in the shapes of the two learning curves. The group using the superior display mastered the task almost immediately, approaching their terminal level of performance after exceptionally few practice trials. Very little learning

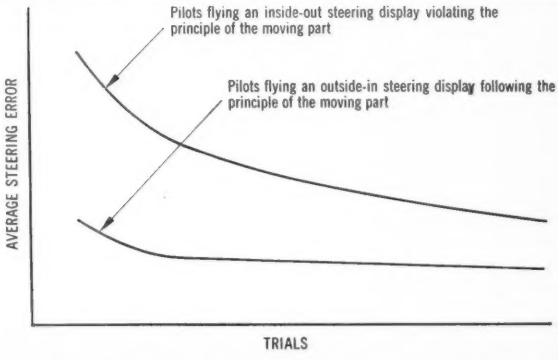
Pilots flying an inside-out steering display violating the principle of the moving part
Pilots flying an outside-in steering display following the principle of the moving part
AVERAGE STEERING ERROR
TRIALS

**Figure 3. Learning curves for two director-type steering displays.**

was required although the task was one of the most exacting encountered in high-speed flight.

Another important finding, not revealed in Fig. 3, was the fact that the individual differences among pilots were much smaller with the superior display. There were no warm pilots or cool pilots; they were all hot pilots.

Such findings have rather startling implications concerning the basic cause of our present pilot selection and training problems. There is little doubt that both can be relieved by proper cockpit instrument and control design.

The explanation of the apparent superiority of displays following the principle of the moving part is not completely understood. The best explanation I can offer is that a pilot when flying contact perceives his airplane as moving against a fixed, stable outside world. *If the world moves, he has vertigo.* Apparently this same natural relationship should be preserved in the cockpit. Clearly the *movement* of a display index is its most compelling stimulus property, and therefore it should represent the movement of the airplane against a fixed index representing the outside world.

The third decision that must always be made concerns the control-aircraft-display relationships. This decision involves such questions as how the controls move and what relationships their movements bear to aircraft performance and to the movements of the indices of the displays.

It should be noted that the improved pilot performance associated with the principle of the moving part can be attributed in some measure to the favorable control-display directional relationships it usually affords. For example, moving the stick to the right causes the moving index of an attitude display of this type to move in the same direction rather than in the opposite direction.

The decision concerning the control-aircraft-display relationships must take into account not only the spatial relationships but also all of the time variant functions between control inputs, performance outputs, and display indications. These time variant relationships can be manipulated in almost any desired manner by employing the techniques known as "quick indicating" or "quickening" the displays and "unburdening" the controls.

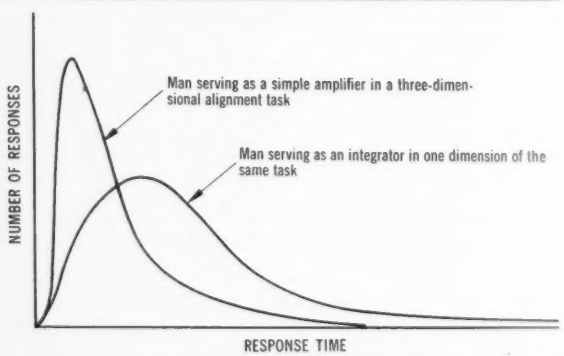
NUMBER OF RESPONSES
Man serving as a simple amplifier in a three-dimensional alignment task
Man serving as an integrator in one dimension of the same task
RESPONSE TIME

**Figure 4. An example of the effects of unburdening.**

A "quickened" display is one that presents a prediction of the imminent response of the aircraft, thus providing the operator with an immediate or "quick" indication of the appropriateness of his control inputs. Quickening can be carried to the point at which the operator's task becomes analogous to that of a simple amplifier in that the indication of the display is directly proportional to the desired control input. Quickening may also be employed to compensate for time lags incurred as a result of filtering or the use of slow sensing devices.

In a similar manner, an "unburdened" control is one that also enables the operator to act like a simple amplifier thus unburdening him of the tasks of acting like an integrator or a differentiator, as he is required to do, for example, in controlling the heading of an aircraft by means of the stick and rudder. Unburdened controls are sometimes referred to as "request" controls since the output performance of the system is directly proportional to the requested performance.

To date, the application of quickening and unburdening techniques to cockpit instruments and controls has been quite restricted. Quickening has been applied to some extent in certain compensatory tracking displays used in flight director systems for homing, landing, and fire control. Quickened displays of this type have limited usefulness as flight instruments since they provide no information concerning actual aircraft performance except in relation to some preselected program. When this point of automaticity has been reached, it is usually profitable to unburden the pilot of this particular task completely.

However, quickening techniques have other possible applications that have not been exploited. For example, they have not been applied to displays of absolute aircraft performance such as heading displays, altitude displays, air-speed or Mach displays, and particularly vertical-speed displays, and it is here that they appear, on the basis of limited experimental evidence, to offer the greatest promise of general application.

Control unburdening techniques have been used in controlling aircraft remotely and by autopilots but have never been employed in connection with the primary aircraft controls. The chief argument against their use has been the question of reliability, but this problem must be solved in any case if we are to make effective use of high-performance aircraft, whether we control them remotely, automatically, or from the pilot's cockpit.

A simple but important example of the effectiveness of control unburdening is illustrated in Fig. 4.

One curve represents the distribution of response times for a three-dimensional alignment task in which the control is designed so that the operator acts as a simple amplifier in each of the three dimensions.

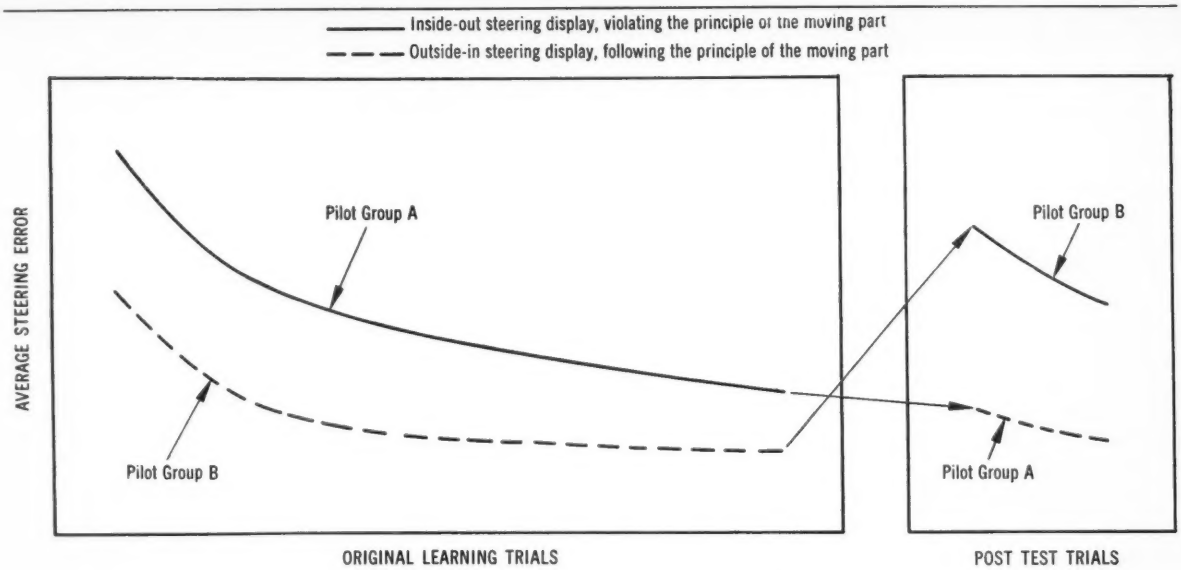
Inside-out steering display, violating the principle of the moving part
Outside-in steering display, following the principle of the moving part
AVERAGE STEERING ERROR
Pilot Group A
Pilot Group B
Pilot Group B
Pilot Group A
ORIGINAL LEARNING TRIALS
POST TEST TRIALS

**Figure 5. Effects of transferring between inside-out and outside-in displays.**

The second distribution was obtained with a partially burdened control that required the operator to act as an integrator in one of the three dimensions only—that is, he was required to control a rate of movement over a period of time in order to accomplish the alignment. In controlling the other two dimensions the operator was still required to act as a simple amplifier.

This was not some abstract task created in a laboratory but one of the most critical performed in any aircraft today. The differences between the two curves can frequently mean the difference between a successful mission and complete failure.

The three basic decisions concerning the design of cockpit displays and controls which have just been discussed obviously represent only a portion of the total problem of designing cockpits for high-speed flight. The few experimental facts presented obviously do not constitute a complete answer to any of the questions raised.

The problems and the facts presented were simply selected to illustrate the following points:

(1) The basic problems in the design of aircraft cockpits can be defined in such a manner that they can be put to critical experimental test.

(2) From such experimental research it is possible to obtain general design principles that will enable the individual engineer or a mock-up board to make practical design decisions on the basis of experimental fact rather than precedent.

(3) The resulting changes in aircraft cockpits could make it possible for any normal person to operate high-performance aircraft with reasonable safety and great precision after a brief period of training, thus relieving our critical selection and training problems while improving the effectiveness of aircraft operation.

There is one more point that always comes last. What would happen during the transition period if airplane cockpits had their old faces lifted rather suddenly? What would happen to the performance of our senior pilots who are highly trained in the use of present cockpit controls and displays and who would first be called upon to fly the new airplanes? This question is always offered as a final and supposedly unanswerable argument against changing our present cockpits. Fig. 5 suggests what the answer might be.

These results are an extension of those shown earlier in connection with the controversial principle of the moving part, although the moving aircraft display in this case was slightly different and not quite so good as the one used in the other experiment. The moving horizon display was the same.

In this experiment the pilots in each group received a series of practice trials on one of the displays and were then transferred to the opposite display.

The results of a single experiment such as this have little generality, but they do suggest an important possibility—namely, that the transition from an unnatural display and control-display relationship to a more natural display having a better relationship to the controls can result in almost 100 per cent transfer of training. This result was also obtained with a group of test pilots already highly skilled in this particular task.

It is interesting and possibly important to note that the converse does not appear to be true. The transition from a natural to an unnatural display encounters serious interference and results in very low transfer of training.

Thus it appears that experienced pilots might have little difficulty transferring to a cockpit designed properly for high-speed flight, but they might then have trouble transferring back and forth between new air-

(*Continued on page 58*)

# Problems Encountered in Calculating Reliability

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## Introduction

After a reliability program has been defined and a satisfactory data-collection system is operating properly, many problems still remain to be solved. The primary purpose of this paper is to explain some of these problems and describe ways in which they were solved at the Bell Aircraft Corporation.

It will be assumed throughout that a basic reliability program has been set up and is functioning smoothly. Methods of disseminating information, and a plant-wide educational program to ensure understanding of this information, have been standardized, but the following problems still remain:

(1) What methods should be used in calculating the reliability of parts, components, systems, and missiles?

(2) Which data should be used in calculating reliability?

(3) Can reliability be calculated for components that have not yet been built and for which no test data exist?

(4) Can reliability calculations be used in obtaining solutions to all problems?

Many of these will be problems only within the group conducting the reliability study. However, each could become a plant-wide problem if the necessary education program is neglected.

In fact, an effort was made to choose problems and present examples which illustrate this need for education and which demonstrate the advantages of conducting such a program.

## Background

Before discussing these problems, however, it is necessary to provide some background information that concerns operation of the reliability program at the Bell Aircraft Corporation and which strongly affects the problems discussed and the solutions proposed in this paper.

### (A) *Definition of Terms*

Since the terms "part," "component," and "system" will be used throughout, a definition of each of these terms is necessary. A part, as it will be used here, is a single element such as a resistor, tube, or switch. A component is a collection of such parts wired together to perform a basic function. An example would be a receiver, transmitter, or amplifier. A system is a collection or components and parts which operate together to perform one of the principal end functions of the equipment. The power plant and telemetering systems are examples of such equipment.

### (B) *Types of Tests*

Many types of tests are performed and must be considered in conducting a reliability program. However, for purposes of this paper, testing can be regarded as having the following levels:

(1) Component—Before installation into the missile, components receive bench tests and environmental tests of various types.

(2) Systems—After parts of systems have been checked out, the systems as a whole are tested individually and in conjunction with each other.

(3) Missile–Complete systems checks in which all systems are operated simultaneously are performed. Since the missile with which the Bell Aircraft Corporation is concerned is an air-to-surface vehicle, it is necessary to test each missile while it is air borne. These test runs are called captive flights. The final flight test is conducted when the missile is dropped from its carrier aircraft.

### (C) *Types of Data*

Data are collected from each of these test levels. If reliability is to be calculated, the following types of data are needed:

(1) Operating time of all equipment with an indication of the conditions under which this time was recorded.

(2) Complete records on all failures that occur.

(3) Serial numbers and location of all components at all times.

Forms have been established on which this information is recorded in the various test areas. Data furnished on these forms are punched into IBM cards and provide the basis for reliability calculations.

### (D) *Methods of Transmitting Data*

It was found that memoranda that are as routine as possible are the best means of transmitting reliability information. In general, experience has shown that engineers and section heads seldom have time to read lengthy explanations of tables and graphs each time the same type of information is transmitted. For this reason, weekly, biweekly, and "periodic" memoranda are sent. Although provision is made for flexibility,

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* Dynamics Engineer.

the memoranda are very similar in form and type of presentation. Monthly meetings are held which supplement these memoranda. The meetings give design and development personnel the opportunity to ask questions, make comments, and suggest improvements that will make the regular presentation of information more meaningful to them.

With this rather brief summary of reliability operations at the Bell Aircraft Corporation, some of the major problems that have been encountered can be discussed.

## Methods of Calculating Reliability

At the Bell Aircraft Corporation reliability is defined as the probability that there will be no failures during the required time, and under the required environmental conditions, of operation of the unit (i.e., missile, system, component, part) under consideration. Since each unit possesses many opportunities for failure, the Poisson Probability Distribution is used in calculating the reliability of each individual unit. Both the definition and the method for obtaining the reliability figure present no problem. They are both clearly defined in various papers on the subject of reliability. Dr. R. R. Carhart's paper, "A Survey of the Current Status of the Electronic Reliability Problem,"* presents the theory that has been adopted by Bell.

### (*A*) *Determining Component Reliability*

The problem arose in trying to relate a large mass of data on failures and operating time to the definition and in trying to keep a large number of engineers and test personnel informed and happy about the methods being used. Component reliabilities were easy to calculate since the available data were set up so that all operating time was listed for each component that was operated for that period. (For example, at the component level of testing, time is recorded for each component individually. At the subsystem and system level, the test group records the operating time under a particular type of test, and this time is mechanically charged against each component that is operating by use of a master deck arrangement with the IBM installation. Thus, a servo-amplifier test might be conducted for 40 min. The IBM operator punches 40 min., the type of test, the date, and the location of the test into a master card. This information is then transferred mechanically into the cards of each component that is operated during this type of test. At the missile test level, time is automatically punched into each card, unless, for some reason, some components are not operated. If this is the case, these cards are first pulled from the deck, and the items listed above are punched into the remainder of the deck.)

Component reliabilities are therefore calculated by obtaining a failure rate and then using a table to determine the probability of having no failures during 1 hour of operation. This figure is called the component reliability.

### (*B*) *Determining System and Missile Reliabilities*

Methods for calculating system and missile reliabilities were more difficult to set up. At first it was thought that system reliability could be obtained quite easily by multiplying together the reliabilities of all components contained in the system concerned and that by multiplying together these system reliabilities a figure for the missile could be obtained. It was soon found, however, that these did not give an accurate indication of the reliability of either the systems or the missile because:

(1) Interactions between, and within, systems are not considered. Frequently troubles occur which cannot be traced to a single component. Something like a noisy servo might appear at one time and not at another, even though no "fix" is made; several components might be suspected and parts might be changed in each of them, with no indication as to which was really at fault. In fact, it might be impossible to determine which system was at fault when trouble occurs during operation of the missile as a whole.

(2) Some failures cannot justifiably be charged against any one system on which operating time is recorded. An example of these would be a failure of the air frame itself.

In order to take these two factors into consideration when reliability figures are calculated, the multiplication procedure cannot be used. To obtain a system reliability, a failure rate is obtained which represents the number of failures and the operating time of the system as a system, or of the system as part of the missile. A similar reliability figure is calculated for the missile itself by using operating time and failures which are charged against the missile as a unit. Both of the reliability figures are obtained by using the Poisson Probability Distribution and represent the probability that there will be no failures of the system or the missile during 1 hour of operation under conditions identical with those encountered during test.

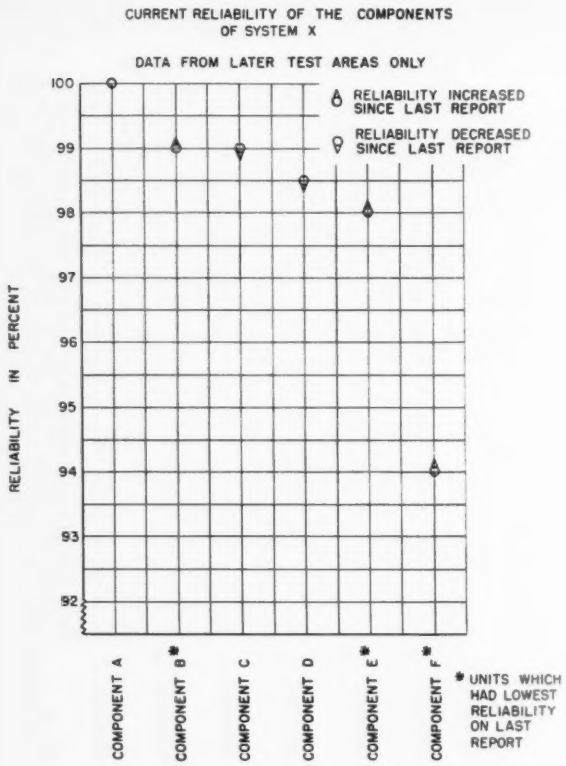
### (*C*) *Determining Part Reliability*

A different problem arose when an attempt was made to calculate part reliabilities. At first it was thought that reliability figures for all parts could be calculated at regular intervals. It was soon learned, however, that this idea was most impractical.

Obtaining a reliability for any given part was easy. Operating time on each part and failure data on each were on hand. Trouble arose when the great multitude of parts in the missile was realized. A wholesale calculation of part reliability was obviously impossible. On the other hand, it was possible to determine reliability of any part in the missile, if necessary. Therefore, part reliabilities are calculated (using operating time of each part of a given type in the missile and

* Research Memorandum 1131, August, 1953.

FIGURE 1




failures of all parts of that type) whenever there is a need-to-know. Some of these needs arise:

(1) In planning a new design, in which it is frequently necessary to know whether Part A or Part B is the more reliable. Reliability figures of both are calculated, if data on both are in existence. If data exist on only one, the reliability of that one is calculated, and a decision is made as to whether or not that part is sufficiently reliable for the new application.

(2) In ordering spares, for which a guide is necessary. Whenever the need for ordering spares arises, the reliability of parts is calculated. Usually all resistors, capacitors, etc., are grouped for this purpose. Reliabilities of tubes and special parts, however, are calculated individually.

(3) As a result of demonstration of poor performance. The reliabilities of all parts that appear to have poor records are calculated. By computing one overall figure and then a figure that represents the reliability of the part in each of its applications, it is possible to compare experience on the same part in each of the circuits in which it is used. This technique is valuable in determining whether the part itself, or the design, is at fault.

### (*D*) *Distributing Reliability Information*

After these procedures for calculating reliability were determined, and before reliability figures were distributed, an extensive educational program was required.

Based on results obtained from the calculations as well as on standards set forth in available literature, reliability requirements were set up and an effort was made to acquaint everyone concerned with these standards, methods of arriving at reliability figures, and ways in which these figures could be of use in attaining a higher missile reliability. It was pointed out that, while the actual figures themselves might or might not have meaning, they did show which units were the least reliable and which units were functioning as desired. Requirements for each unit were set up as follows:

| | |
|---|---|
| Part, | 99.99 per cent |
| Component, | 99.9 per cent |
| System, | 99 per cent |
| Missile, | 95 per cent |

It was pointed out that these are necessary, but not sufficient, conditions. In order for these conditions to be acceptable for some units, others must be significantly more reliable.

It will be noted that these minimum requirements agree quite well with those proposed in available literature on reliability. Even more important, however, is the fact that the figures that were obtained were of the same order of magnitude. Considering only component reliabilities for the moment, there were many units that demonstrated reliabilities above 99.9 per cent. There were also some that fell below this figure, and there was a spread to those values that were below which clearly indicated the need for re-examination of certain components.

After these requirements were formalized and widely published, periodic reports listing the reliability of each component in each system were introduced. Although the format is extremely flexible, and at one time was changed whenever a monthly meeting was held with the design group concerned, a standard method of presentation is used.

The data are presented in a report consisting of a graph and a memorandum. The graph (as shown in Fig. 1) shows the current reliability of each component in the system under consideration. Components are listed in order of descending reliability. Arrowheads indicate the direction in which the reliability is going in each case; those units that had the lowest reliability on the preceding report are starred. The memo accompanying this graph explains the method of obtaining data and analyzes the reason for the low reliability of the poorest units. Large-scale improvements are mentioned, and reasons for improvement are presented.

The problem of plant-wide education, however, is paramount in all of these considerations. In the case of one such report, for example, the component that demonstrated the lowest reliability was an item that could be replaced with a unit of much higher reliability. The engineer, seeing that this component had the lowest reliability and was, therefore, the most likely to cause a failure in flight, initiated a request for

a component change. The reliability figure contained in the report was cited in his request. The request was turned down, because the person who had to approve it was not on the distribution list of the original report and the reliability figure, in itself, was meaningless to him. Fortunately, it was possible to spend 3 days on a rapid education program, and the request was reinstated and approved. The person who turned down this request is now on distribution lists of all similar reliability reports. However, it is felt that such unfortunate occurrences will never be completely eliminated.

In general, the program of educating personnel to understand and accept reliability figures is complete. Little further trouble is expected, and much has been gained through their use.

## Data Used in Calculating Reliability

Decisions as to which information should be used and which should be omitted must constantly be made. After reliability figures have been distributed, if the feedback of information to the Reliability Group is adequate, there will be many questions about the data being used and many suggestions as to methods of improving the reliability of the figures. These will include the suggestions that some of the data might be omitted and that additional information should be included. Therefore, in establishing methods for calculating reliability, reasons for including or not including each type of data are necessary.

Methods should be sufficiently flexible, however, to assure that compromises can be reached if necessary. If design and development engineers do not understand and do not agree with methods used in calculating reliability, they will not use the resultant figures no matter how many advantages can be gained from them.

### (A) *Sources of Data*

Some of the questions that will arise when sources of data are considered include:

(1) Should test results from the component level be included?

The purposes of component testing are the location of future trouble areas early in the program and the performance of an additional inspection function (i.e., by subjecting units to bench tests many workmanship errors can be found). Most of the troubles that are found in these tests indicate troubles such as improper wiring, poor soldering, or, in the case of the first unit or two of a given type component, failures caused by inaccurate drawings or incorrect test procedures. It is felt that individual components would be penalized if the results of these tests were used in arriving at reliability figures.

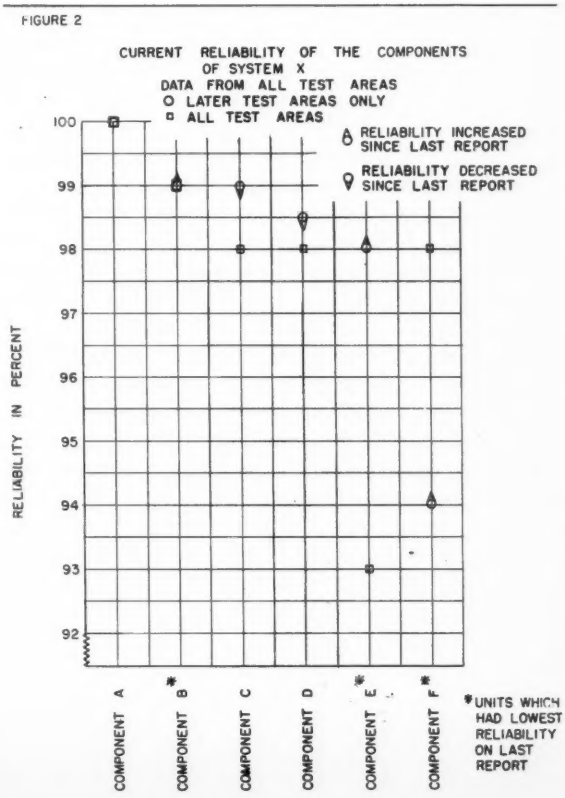
Reliability figures that use results of component testing are useful, however, in that they show which units are causing the most trouble at this level. They also provide assurance that these tests are adequate or show that they are not. For this reason these figures are calculated and presented in periodic reports, as shown in Fig. 2.

Reliability figures based on the results of all testing (including component level) should be lower than those representing experience from later test areas only. If they are not (Component F, Fig 2) action is indicated. Either early testing is not sufficiently stringent to ensure that the component will operate satisfactorily in later test areas, or the trouble is being induced by the interaction of components. Either of these cases would necessitate a more accurate reproduction of these conditions during testing at the component level.

If reliabilities that include component experience are lower than those that do not, they could be too low (Component E, Fig. 2). This also indicates a need for investigation. For example, in the case of one part, reliability figures that included this level were extremely low, whereas the part never failed at later test areas. Investigation showed that only one out of every twelve tested was passing. This, in turn, resulted in the discovery that the test specification was wrong. In this case, the items concerned were purchased and personnel at the component test level assumed that the parts received were incorrectly built. They did not notify Engineering of the difficulty they were experiencing.

A similar situation might, at another time, mean that a change in vendors should be made. Or, again, it might indicate a basic weakness in the design such

FIGURE 2



that combinations of tolerances or the use of unselected parts make it difficult, if not impossible, to build a satisfactory component, but that once the proper combination of parts is obtained, the unit will operate efficiently in the missile. With the establishment of a satisfactory feedback system, all of these factors can be determined with a minimum of delay.

(2) How should data from captive flights be handled when reliability figures are calculated?

Information from captive flights and final flights is treated separately. It is necessary to consider data from these experiences individually so that they can be constantly compared with the results of testing at earlier levels. An effort must be made to reproduce any troubles that occur and to change earlier test procedures so that all troubles will eventually be discovered early in the test program in order to avert possible flight failure or, at the very least, costly delays late in the test program.

Although it is easy to analyze each malfunction in detail and compare it with the past history of the unit, methods of obtaining reliability figures based on these flights have not yet been finalized at Bell Aircraft. Every method tried has led to difficulties in handling the data.

There is some feeling that all flights are either 0 per cent or 100 per cent reliable. It is no doubt true that a reliability figure could be obtained after a great number of flights. However, the degree of confidence which could be given to such an answer based on ten or 20 flights is very small, and, unfortunately, it is during these early flights, before the final design is frozen, that results are needed. It is felt, therefore, that a figure somewhere between 0 and 100 per cent has some meaning and can be valuable in showing trends among early missiles. A method for handling these data is needed. This method should provide a true picture of experience early in the flight-test program and should be easy to explain to all personnel concerned with the development and design of the missile and its components.

(3) How should data from other companies be used in calculating reliability?

Since there are no standardized methods of calculating reliability, it would be impossible to compare the figures obtained at Bell Aircraft with those obtained for the same or similar units at other companies. Such experience can be mutually useful only insofar as the sources and usage of data are known. In most cases original data are more valuable.

Certain specific types of information which are received from other manufacturers can be incorporated into a reliability program. In one instance, for example, a major component that received no preliminary testing at the Bell Aircraft Corporation was used in the missile. It received only one test prior to the captive flight and was of such a nature that it was suspected that the component would wear out if subjected to many tests. With the small amount of data that could be collected within the plant, little could be determined about the possible life of the component. For this reason, the vendor was asked to supply information concerning the test history of each unit that was shipped to Bell. This information has been incorporated into the reliability study and is proving useful in determining to what extent the reliability of the component is a function of time.

It is felt that a well-organized plan for correlating the experiences of various manufacturers will be of great value in the future. At present, however, no exchange of actual reliability data is feasible.

Briefly summarizing the above, it has been necessary to calculate two sets of reliability figures for each component. One of these reflects data obtained from all test areas. The other includes only data obtained after the component has been assembled into the missile. This latter figure is called the component reliability. System and missile reliabilities are calculated from experience gained during the operation of systems and missiles only. Captive flight and final flight data are handled separately. A satisfactory method for obtaining reliability figures from these data is being sought. Information from other companies is used only in special cases when the need arises.

### (*B*) *Causes of Failure*

Usually design personnel are most concerned with whether or not human error (i.e., poor workmanship, mishandling, etc.) failures are charged against the unit when reliability calculations are made. They feel that this would be unfair. The difficulty arises when it is realized that this type of trouble will never be eliminated and that reliabilities calculated from data that exclude these troubles present an unrealistically favorable result. Also, many cases can be cited which show that many failures that appear to be caused by poor workmanship are basically caused by poor design. One component, for example, failed consistently because it was miswired but never for any other reason. An investigation proved that the drawing, while accurate, was so complex that the component was almost impossible to build. In other cases, similar collections of data have shown a need for tightened inspection or improved assembly methods. A great deal of valuable information would be lost if these failures were not considered. Having decided that this data had to be considered, there was still the problem of devising a method for feeding back this information while keeping everyone informed. It was felt that an ideal solution would be to graph reliabilities with and without human error.

An investigation was made in order to determine the effect these failures would have on the reliability figures then being used (i.e., figures in which all types of failures were included). This investigation showed that a majority of the human error failures were discovered at the component level and that a majority of the failures that occurred at this level were caused by human error. In only one case of those considered would

human error affect the reliability of a component at later test areas.

A graph was prepared which included reliability figures with and without human error at both test levels. The graph was extremely cluttered and produced no results that could not have been obtained from the graph presented in Fig. 2.

As a result of these findings, an extensive educational program was conducted in order to acquaint personnel throughout the plant with the fact that human error failures are included in all reliability calculations. It was pointed out during the course of this program that whenever human error affected the reliability obtained, this would be specifically indicated and the component would not be penalized.

This arrangement has worked out satisfactorily, no doubt because key personnel were kept informed and because all reliability figures are carefully screened in order to determine the cause of low reliability. By including these human error failures, they are kept constantly in the minds of those who can do the most to combat them.

## Calculating Reliability for Items on Which No Information Exists

After the reliability program has been sufficiently publicized and information on the reliability of a large assortment of components and parts has been provided to miscellaneous personnel for a variety of reasons, a large number of requests for similar information are received. A favorite type of question involves a request for the reliability of a component or system which has not yet been built, which has never been used before, and on which no information exists.

It would be simple to say that there is no information on this component or system. However, it is felt that providing information of this type is one of the major goals of the reliability program. Therefore, in an effort to devise methods that will produce valid results, an attempt is made to estimate the eventual reliability of the component or system. At present two methods are used in this analysis:

(1) The component is broken down into parts, and the reliability demonstrated by each part in its other applications is determined. In cases where a part has never been used before, the reliability of a similar part is used. These reliabilities are then multiplied together to obtain an estimate of the component reliability. This figure, in itself, would be meaningless except that usually, upon obtaining the result—together with a strong statement on its limitations—the designer produces another version of the same component with a request that this be analyzed in a similar fashion. In introducing a second or third unit in this way, the results of the analysis become more valuable, since comparisons of the estimates can be made and the most reliable design selected.

(2) An accurate estimate of the number of tubes in the system is obtained. Although the exact nature of the relation between tubes and reliability is not known, it has been found that there is a relationship between the two. Therefore, for systems that employ a large number of tubes, estimates based on the number of tubes used in each system are made.

It is felt that these techniques are not yet as useful as desired. The best method of refining the techniques, however, appears to be to make educated guesses and then keep careful records of what actually results when the component or system is put into use. Results will not appear for several years.

An exchange of information among all companies on techniques used and results obtained would be of great value.

## Are Reliability Calculations the Solution to All Problems?

Although reliability figures provide a scientific starting point in increasing reliability, they are not a cure-all, regardless of how adequate the educational program has been, and no matter how many uses are found for them. Many major problems are not indicated by the figures thus obtained. These problems are best described in the following manner:

(A) At times the component that has the lowest reliability is not the one most in need of immediate redesign. Another component might be more critical in that its failure would make it impossible to continue with the test program; a component that fails rarely might cause serious delays in the program when it does fail. The fact that either of these components failed on even one occasion might be conclusive. All phases of the data must be constantly examined so that troubles can be corrected in the most efficient manner; only when all other factors are equal can reliability figures be the sole basis for decisions.

(B) Various types of data do not lend themselves to a calculation of reliability. At present, as previously explained, the analyses of captive flight and final flight data are in this category. Worth-while results are obtained, but they cannot be analyzed statistically. Another type of data that do not allow such analysis is a detailed summary of causes of failure. Causes can be broken down in many ways; valuable information can be gained from each. For example:

(1) Graphs can be prepared which show how many workmanship or human errors are occurring at each test area. A need for closer inspection at later test areas or a change in test procedures at earlier areas might be indicated if excessive numbers of these items are not found until late in the program. Items such as incorrect wiring, poor soldering, part missing, and need for better communication can be considered separately.

(2) Records of when tube failures occur are also valuable. It is useful in determining how many failures occur before tubes have been operated for 50 hours. and how many occur before 100 hours' of operation, Such studies might indicate a need for a tube-aging

program or will prove that such a program is unnecessary

### Conclusions

Briefly reviewing the factors presented in this paper, the following conclusions can be drawn:

(1) Reliabilities of parts, components, systems, and missiles are most realistic if each is calculated individually rather than by a multiplication process. Reliabilities of all components in a given system cannot be multiplied together to produce a system reliability; the reliability of all components in a missile cannot be multiplied together to produce missile reliability.

(2) After an educational program has been conducted in which all key personnel are informed about reliability standards that have been set up, as well as about methods of arriving at reliability figures, best results can be obtained by issuing routine reports that are easy to read and which can be changed as the need arises.

(3) Data from the component test level are valuable and should be included on the graphs that accompany these memoranda. However, these data do not provide a true picture of the reliability of the component.

(4) A method for determining captive flight and final flight reliabilities is necessary.

(5) Actual reliability data obtained from other companies are of doubtful value. However, information concerning operating time and failures of specific items can be obtained from other vendors for inclusion in a reliability study.

(6) Human error failures can be included in all reliability calculations. However, if they affect the reliability of a component, the component should not be penalized.

(7) An important future use of reliability information is in the field of predicting the reliability of new, untested components. Considerable research must be done and an interchange of information must be promoted before satisfactory methods can be established.

(8) Although reliability calculations provide an ideal starting point in determining the location of sources of trouble, there are many tools that are more valuable in improving reliability.

## Wing Design for Practical High-Speed Aircraft

(*Continued from page 46*)

of parts to be produced and the rate at which they are to be turned out. As time goes by all designs must be improved to keep them competitive. To the extent that these changes involve detail revision to structural components, it is wise to select the original design type with a view to accomplishing these future design changes most expeditiously and at the lowest possible cost throughout the manufacturing program.

## Designing the Cockpit for High-Speed Flight

(*Continued from page 51*)

planes and old airplanes. This might result in a certain amount of inconvenience. For a few years we might have to qualify pilots to fly only certain types of airplanes. Practically speaking, this has always been the case and has never been a serious problem.

In any event, we have little choice in the matter. The higher performance of our modern airplanes requires higher performance from our pilots, and this cannot be attained with present cockpit displays and controls.

# Thermal Considerations in Electrical Accessory Design

E. W. CORNWALL*
*Douglas Aircraft Company, Inc.*

## Introduction

THE QUANTITY OF ELECTRICAL EQUIPMENT in aircraft has increased many times in the last 10 years. Fig. 1 shows a mobile training display of the electrical system of the Douglas SBD-5 Dauntless airplane of 1944. Fig. 2 shows the increased electrical system complexity of the Douglas AD-4 Skyraider, a 1951 descendant of this same type of propeller-driven aircraft. In the latest 1954 high-speed jet aircraft, the complexity and number of electrical components are much greater than those shown for the AD-4.

The increase in electrical components, especially with the advent of jet engines and higher speeds, has stemmed from the fact that the average pilot, no matter how well trained, cannot think efficiently enough or function fast enough to keep up with a modern high-speed aircraft. This is especially true in bad weather or in military combat. The pilot, therefore, must have numerous electrical and electronic aids that enable his mind and muscles to cope with the numerous high-speed decisions and reactions which must be made for successful high-performance flights. Some experts believe that the 14 to 1 score in our favor for aircraft combat casualties in the Korean War was achieved in good part by the help of these electrical and electronic aids with which our planes were equipped.

One fact that cannot be overemphasized is that to pay off in the manner noted above the electrical aids must function reliably for long periods of time with a minimum amount of maintenance. One of the chief antagonists of reliable, accurate electrical and electronic functioning is heat. Ironically, electrical equipment is its own worst enemy in this respect as it cannot function without giving off quantities of heat. Heat from the sun, heat from the aircraft power plant, and heat generated by the velocity of the aircraft passing through the atmosphere all add their share to the total quantity of thermal energy adversely affecting electrical equipment. To keep these electrical aids functioning reliably, the flow of heat from all sources must be diverted or absorbed, so that the equipment temperature can be kept within the limits necessary for reasonably long life and efficient operation.

Presented at the Accessory Design Problems Session, National Summer Meeting, IAS, Los Angeles, June 21–24, 1954.

* Design Engineer, Equipment and Interiors Section, El Segundo Division.

## Discussion

In providing means of removing heat from electrical accessories, the aircraft designer must at all times be extremely conscious of size, power consumption, and weight of the cooling devices used. If the weight of the electrical gear plus its cooling systems is allowed to get too heavy, too hungry for power, or too complex, the fighting superiority of military aircraft or the economic superiority of commercial aircraft can quickly disappear.

Electrical equipment cooling is not obtained cheaply. Estimates based on late-model aircraft of approximately Mach 1 speed potential indicate that, for each kilowatt of heat energy removed from Specification AN-E-19

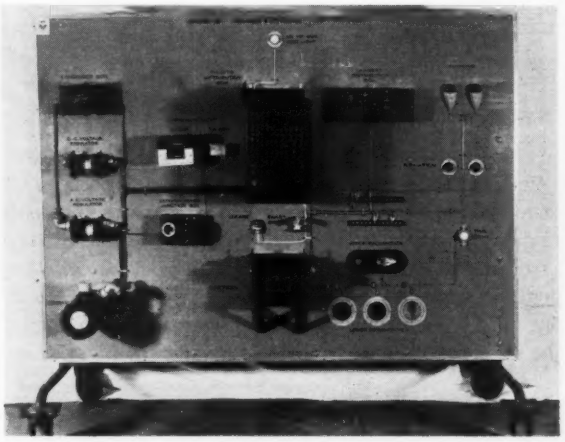


FIG. 1.

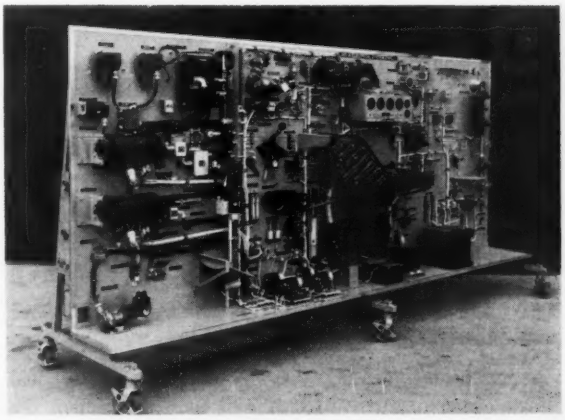


FIG. 2.

type of electronic equipment, 15 lbs. of cooling equipment must be added. In addition, approximately 11 kw. of power are taken from the aircraft engine to drive this 15 lbs. of cooling equipment during sea-level, maximum-speed conditions. This latter figure for power consumption can also be stated in pounds of weight. For an average jet engine, 11,000 watts of power are equivalent to approximately 10.6 lbs. of fuel consumed per hour of flight. Thus, for a small military aircraft with 1-hour, high-speed flight duration and 6-kw. electronic gear heat dissipation, the total take-off weight penalty for cooling this electronic equipment alone would be about 160 lbs.

Considering an average growth factor of 10 (see Fig. 3) and a production cost factor of $40 a pound, the cost of this electronic equipment cooling in a production airplane will be 160 by 10 by $40, or $64,000 per airplane in order to maintain original performance. For those to whom dollars are meaningless statistics, this is equivalent to approximately eleven Cadillac convertibles complete with radios and heaters.

The designers at the El Segundo Division of Douglas Aircraft Company, Inc., believe the above cost is much too high, and they desire to cut it. However, they are prevented from making desired savings in weight and power consumption by certain built-in characteristics of the electrical accessories themselves. In the following paragraphs the nature of these built-in obstacles to efficient cooling design will be discussed.

#### (*a*) *Electrical Accessory Inefficiency*

The efficiency of many electrical components is low. For example, in the average electronic "black box" about 96 per cent of the electrical power input ends up as dissipated heat that must be removed by the cooling system. Invention and/or perfection of electrical components with higher overall efficiency can save weight not only by reducing the cooling load but by reducing the size of the aircraft's generators and wiring systems as well.

#### (*b*) *Excess Size and Electrical Input*

Many electrical accessories are larger in size and higher in wattage input than can be justified on the basis of $40 times a growth factor of 10 for each pound of excess weight, or for each kilowatt of excess power. In some types of circuits, especially computing circuits, it is possible to miniaturize not only the physical size of the electrical components but also the magnitude of circuit amperages and voltages. This saving in power, as noted above, will save weight in cooling system, generators, and wiring. These savings will be in addition to the primary savings in weight and space achieved by small physical sizes.

#### (*c*) *Duplication of Function*

It has been found many times that various electrical packages on a given aircraft will each have elements performing identical functions. A common example of this is the gyroscope. Some aircraft carry three or four gyroscopes, each with its own hot little motor. One master gyro could easily supply the necessary impulses to all the packages.

#### (*d*) *Low Maximum Component Temperature*

No matter what type of heat transfer is involved—whether convection, conduction, or radiation—the equipment cooling process is effected as a function of the temperature difference between the electrical element surfaces and that of the cooling medium. Since lowering the temperature of the cooling medium costs much weight and power (see Fig. 4), it appears that the greatest savings can be achieved by raising the maximum allowable average package surface temperature. This can be done by two methods:

(1) *Use of new electrical design principles and new materials that will permit construction of electrical packages more resistant to high temperatures*—Improved materials such as silicones and fluorides can replace wax paper and rubber. High-temperature ceramics can replace conventional glass and, in some cases, metal construction.

(2) *Use of all materials at temperatures that are very close to their maximum allowable temperature limit*—To achieve such design, it is necessary to spend considerable thought and test time on the interior arrangement of electrical packages. It should be mentioned here that Air Force Technical Report No. 6579, entitled *Thermal Evaluation of Air Cooled Electronic Equipment*, will be of considerable value in such development test programs.

#### (*e*) *Low Heat Exchanger Effectivity*

In the design of heat exchangers there is a term called "heat exchanger effectiveness." For a heat exchanger in which air is heated by some higher temperature fluid, the effectiveness would be stated as in Fig. 5.

For electronic equipment this statement of heat exchanger effectivity might be changed to fit the situation as shown in Fig. 6.

This heat exchanger effectivity expression gives a measure as to how effectively the cooling fluid is utilized. By means of this measuring tool one type or configuration of equipment can be accurately compared with others to determine which type or configuration has the best design from a heat-transfer standpoint.

Most electrical packages rate rather poorly on heat exchanger effectiveness. To increase the effectiveness, the cooling air (or other cooling fluid) must be introduced directly to the hot element surfaces with as high a velocity and as great a turbulence as can be maintained with reasonable pressure drops.

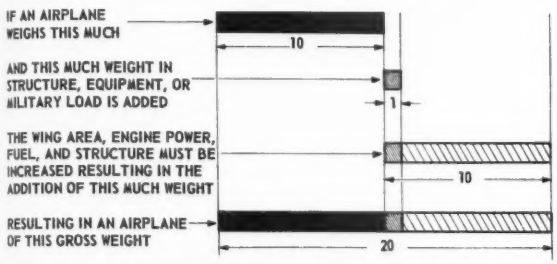
#### (*f*) *Incomplete Thermal Data on Electrical Equipment*

(1) In designing cooling systems for air-borne electrical equipment, the aircraft designer is at present faced with a difficult problem. The cooling system must provide adequately for the cooling of specified

**GROWTH FACTOR**

**In conducting this study, it was necessary to establish several weight and cost factors that are rather arbitrary but represent the state of aircraft design at the present time. Among these is the "growth factor," a term applied to the increment by which the gross weight of an airplane increases for every unit of equipment weight added if performance, strength, and combat radius are held constant. This factor varies from a value of 4 for some of the old propeller airplanes to as much as 16 for some of the more modern jet fighters. For all the current models in which this factor has been investigated, a factor of 10 appears to be about average and has therefore been chosen arbitrarily for purposes of this study.**

FOR EXAMPLE:


IF AN AIRPLANE WEIGHS THIS MUCH
10
AND THIS MUCH WEIGHT IN STRUCTURE, EQUIPMENT, OR MILITARY LOAD IS ADDED
1
THE WING AREA, ENGINE POWER, FUEL, AND STRUCTURE MUST BE INCREASED RESULTING IN THE ADDITION OF THIS MUCH WEIGHT
10
RESULTING IN AN AIRPLANE OF THIS GROSS WEIGHT
20

**Thus, if equal performance is maintained, the addition of a weight equal to 10 per cent of the weight of the airplane will double its gross weight.**

FIG. 3.

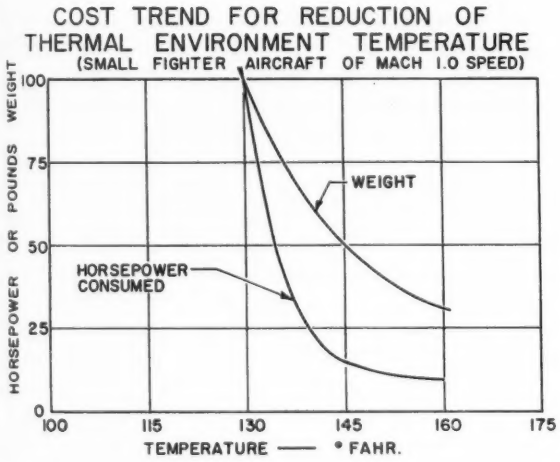



FIG. 4.

$$\text{EFFECTIVITY} = \frac{\left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{AIR LEAVING}\\ \text{HEAT EXCHANGER}\end{array}\right) - \left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{AIR ENTERING}\\ \text{HEAT EXCHANGER}\end{array}\right)}{\left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{HEATING FLUID}\\ \text{ENTERING HEAT}\\ \text{EXCHANGER}\end{array}\right) - \left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{AIR ENTERING}\\ \text{HEAT EXCHANGER}\end{array}\right)}$$

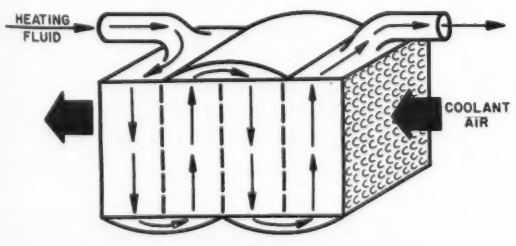



FIG. 5.

$$\text{EFFECTIVITY} = \frac{\left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{COOLING FLUID}\\ \text{LEAVING EQUIPMENT}\end{array}\right) - \left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{COOLING FLUID}\\ \text{ENTERING EQUIPMENT}\end{array}\right)}{\left(\begin{array}{c}\text{AVERAGE WEIGHTED}\\ \text{TEMPERATURE OF}\\ \text{ELECTRICAL ELEMENT}\\ \text{SURFACES}\end{array}\right) - \left(\begin{array}{c}\text{TEMPERATURE OF}\\ \text{COOLING FLUID}\\ \text{ENTERING EQUIPMENT}\end{array}\right)}$$

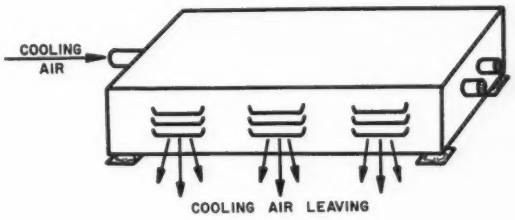



FIG. 6.

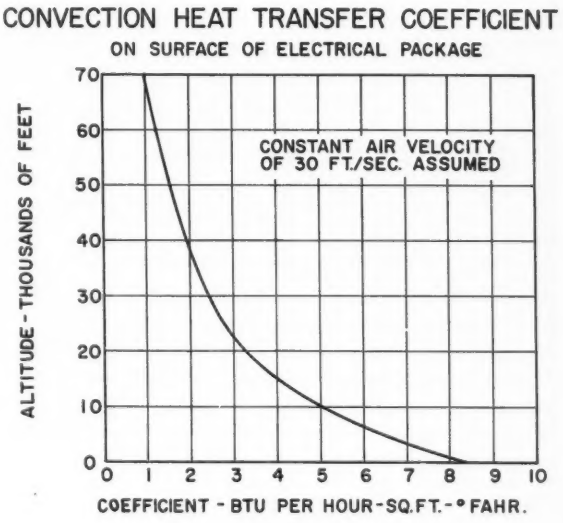



FIG. 7.

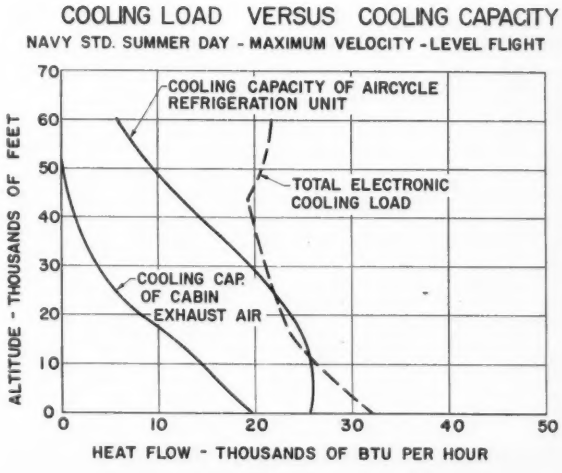



FIG. 8.

equipment, but, at the same time, it must be highly efficient, compact, and lightweight. Excess capacity in the cooling system means that the aircraft performance will be unnecessarily reduced or that the airplane cost will be unnecessarily increased. With the present trends toward larger and more complex electrical systems with correspondingly larger cooling systems, the aircraft designer cannot afford to guess or to apply an estimated safety factor. He must know exactly the magnitude of the cooling requirements of each item of equipment. Unfortunately, on the majority of electrical items presently being installed, the only data available are the electrical input, physical dimensions, and the fact that the equipment may meet the ambient temperature requirements of Paragraph D-2s(1)a of AN-E-19 when tested under unknown laboratory conditions of air velocity and radiation. The type of thermal data actually needed is fairly complex. It is not possible to discuss the matter fully here. However, a complete list of data required for accurate engineering evaluation of equipment cooling requirements will be found in the Appendix.

(2) Here are a few comments on the type of thermal data required: The first of these is that it is highly important that the cooling requirements of the equipment be stated versus altitude. The reasons for this become apparent when the basic heat-transfer considerations are studied. For air-cooled equipment, the convection heat-transfer coefficient varies as a function of the cooling air density; thus, convection heat transfer at altitude is much less than at sea level. This is graphically shown by Fig. 7. The significance of this fact is that, to achieve the same electrical element surface temperatures at altitude as at sea level, the altitude ambient temperature conditions and/or the blast air cooling temperature must be much lower than at sea level.

(3) Another factor that makes the altitude data important to the air-frame designer is that the cooling capacity of most known practical cooling systems decreases with altitude. Therefore, extremely high altitude can easily be the most critical point for cooling. To illustrate this point, typical cooling-load and cooling-system capacities for a hypothetical small jet fighter aircraft of about Mach 1.0 performance are presented in Figs. 8, 9, and 10.

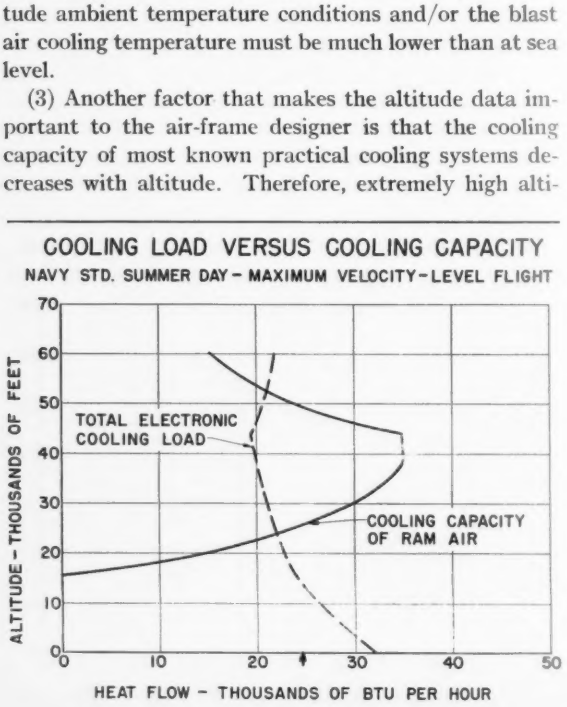

COOLING LOAD VERSUS COOLING CAPACITY
NAVY STD. SUMMER DAY – MAXIMUM VELOCITY – LEVEL FLIGHT
ALTITUDE – THOUSANDS OF FEET
TOTAL ELECTRONIC COOLING LOAD
COOLING CAPACITY OF RAM AIR
HEAT FLOW – THOUSANDS OF BTU PER HOUR

FIG. 9.

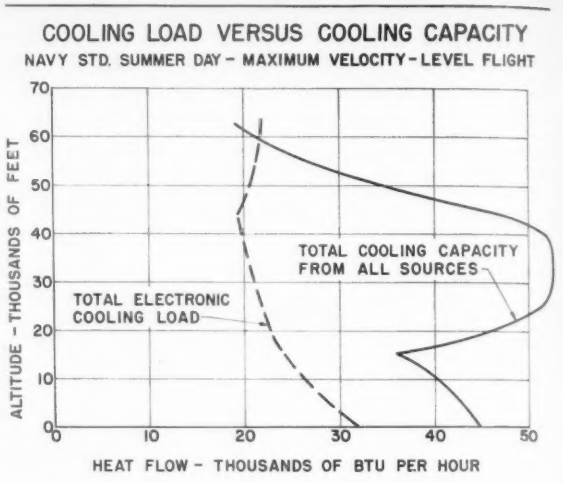

COOLING LOAD VERSUS COOLING CAPACITY
NAVY STD. SUMMER DAY – MAXIMUM VELOCITY – LEVEL FLIGHT
ALTITUDE – THOUSANDS OF FEET
TOTAL COOLING CAPACITY FROM ALL SOURCES
TOTAL ELECTRONIC COOLING LOAD
HEAT FLOW – THOUSANDS OF BTU PER HOUR

FIG. 10.

(4) Some other items of information which are very important but seldom available to the aircraft designer are:

(a) Temperature rise of critical elements versus time and ambient thermal conditions.

(b) Life of critical elements versus ambient thermal conditions.

These two items can help the aircraft designer arrive at compromises in cooling capacity in which life of equipment can be balanced against added weight and cost of the aircraft.

Returning now to the main thought regarding thermal data procurement, it is desired to point out that a difficult timing problem exists. In many instances the design of an aircraft and its equipment cooling system must progress parallel to the design of electrical or electronic accessories for that aircraft. In such instances it is impossible for final electrical accessory tests to be furnished in time to assist in design of the aircraft cooling systems. The only answer to this situation is the establishment of close and continuous liaison between the aircraft and electrical equipment manufacturers and realistic, practical specification requirements from the standpoint of both manufacturers. Both the Air Force and the Navy have indicated interest in changing existing specifications pertaining to this matter, and many of the comments of this paper have already been directed to them.

Before closing, it seems that a few words should be devoted to the types of equipment cooling systems which are commonly in use or which look feasible for the future. Two or three general types appear the most practical.

(a) For the conventional military aircraft with speeds up to approximately Mach 1.5 and with ceiling altitudes below 70,000 ft., it appears that the presently

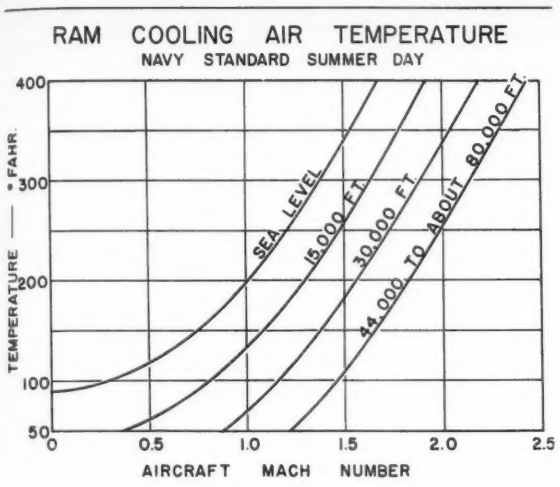



FIG. 11.

used air blast cooling will continue to be the most practical, economical method.

(b) For speeds and altitudes greater than the values noted, it is likely that evaporative liquid coolants will be used, probably on an expendable basis. A metal conduction air-frame skin radiation cooling system may also have possibilities at extremely high altitudes.

With the exception of electrical equipment for the superperformance classifications noted in (b), it is believed that electrical equipment components should be designed for blast air cooling. Four principal sources of air for this type of cooling can be made available on military or commercial planes.

(1) Ram air.

(2) Exhaust air from an air-conditioned cabin.

(3) Cold refrigerated air diverted from the cabin refrigeration unit.

(4) Refrigerated air from a special equipment refrigeration unit.

As is shown on Fig. 11, the use of ram air is limited to high altitudes or low speeds.

Exhaust air from air-conditioned cabins is delivered to the equipment at 80° to 90°F. The cooling effect of this air is valuable, but the quantity and pressure available are limited.

Refrigerated air diverted from an oversized cabin refrigeration unit is sometimes an economical source of cooling air. However, its use should be carefully analyzed, as this type of system complicates the cabin temperature-control system and delivers cold air on an inefficient basis when the cabin is pressurized.

The use of a special refrigeration unit for equipment cooling is practical when equipment cooling loads are large.

Usually the equipment cooling system of an actual airplane uses a combination of two or three of the above sources of cooling as illustrated previously.

## CONCLUSIONS

In the above discussion, the high cost of electrical accessory cooling has been pointed out. The major obstacles to reduction of these costs are described. Removal of these obstacles depends on the action of electrical accessory manufacturers, as follows:

(a) Use of more efficient electrical devices and higher-temperature materials.

(b) More effective design of electrical packages from a thermal standpoint.

(c) More thorough, complete knowledge of the thermal characteristics of electrical equipment in accordance with the outline of the Appendix.

(d) More rapid transmittal of these thermal characteristics to the aircraft manufacturer.

In order for this country to retain the high air combat superiority demonstrated in the Korean War, it is essential that the aircraft manufacturers deliver to our Armed Forces the best overall airplane.

At the moment, from a specification standpoint, the electrical equipment designer is responsible only for the weight of his equipment. The aircraft designer is responsible for the weight of the cooling and power-supply systems. Actually, it is the total of these things which affects the total weight, cost, and performance of the overall airplane. Achievement of a decrease in the total weight and cost chargeable to the electrical equipment with a split responsibility such as this requires considerable cooperation and an understanding of the overlapping design problems.

If such cooperation is not forthcoming from the electrical industry, then the aircraft manufacturers themselves will be forced by competition to redesign and/or repackage electrical accessories to save weight and space and achieve better cooling characteristics. Even now, this is being done for the new Douglas A4D-1 Skyhawk, as shown by Fig. 12. Actually, Douglas El Segundo prefers to design the aircraft rather than electrical components. Therefore, it is hoped that this presentation will accelerate the required cooperation and understanding of mutual problems in the field of electrical accessory cooling problems.

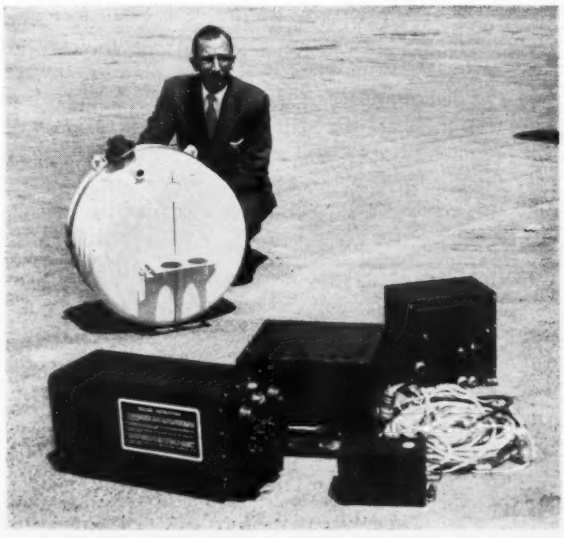


FIG. 12.

## APPENDIX

### Data Required for Accurate Engineering Evaluation of Electrical Accessory Cooling Requirements

(1.0) From the standpoint of a heat-transfer engineer designing accessory cooling systems, there are three general types of accessory packages presently used on military aircraft. These are:

(1.1) Accessories packaged in boxes* vented to the air-frame compartment by louvers or holes. Also, sealed boxes with a variable pressure inside.

(1.2) Accessories packaged in sealed boxes whose interior is maintained at sea-level, or higher, constant pressure.

(1.3) Accessories packaged in boxes vented to the air-frame compartment but supplied by cooling air ducted directly into the equipment package, or equipment packaged in sealed boxes whose interior is maintained at sea-level, or higher, pressure but with cooling air ducted through an internal heat exchanger.

(2.0) Each of the above types of packages presents a somewhat different problem in stating the minimum data necessary to establish its thermal characteristics and cooling requirements.

(2.1) For the type of package noted in (1.1), cooling requirements should include:

(2.1.1) Heat input rate and required heat dissipation rate in watts or B.t.u. per hour.

(2.1.1.1) Where parts of equipment operate discontinuously or at a varying per cent of their full load rating, this should be noted together with the heat input vs. time, altitude, or other pertinent variables.

(2.1.1.2) It should be noted that the heat input to the accessory package and the required heat dissipation rate are equal only in the prolonged steady-state condition. The difference between the two is ordinarily the heat that is absorbed into the equipment itself as a function of the specific heats of the various materials used in its construction. Where the mass of the accessory is large and the time of accessory temperature stabilization long, the required heat dissipation rate can be much lower than the heat input rate for short-time flights. Where this factor is important, the heat dissipation rate should be stated as a function of time or other pertinent variables.

(2.1.2) Maximum permissible ambient temperature conditions vs. minimum average cooling air velocities over the equipment and vs. altitude and heat input rate. Ambient temperature conditions are here defined as the temperature of the ambient air and the temperature of surrounding solid surfaces (wall temperatures of test chamber or airplane compartment).

(2.1.3) Temperature† rise of critical equipment elements vs. time and heat input in maximum ambient conditions noted in (2.1.2).

(2.1.4) Life of critical elements vs. temperature of critical elements.

(2.1.5) Approximate envelope dimensions, position and size of louvers or other openings, location and performance (vs. altitude) of any internal fans, location and dimensions of any special heat-transfer fins, and color and type of surface finish.

(2.1.6) Provisions for attachment of equipment to aircraft. For example, accessories mounted by shock mounts are effectively isolated thermally from the airplane structure, but accessories mounted metal-to-metal on fuselage structure may achieve considerable cooling or heating by direct conduction.

(2.2) For the type of package noted in (1.2), cooling requirements should include:

(2.2.1) Heat input rate and required heat dissipation rate in watts or B.t.u. per hour. See also paragraphs (2.1.1.1) and (2.1.1.2).

(2.2.2) Maximum permissible temperature of outside surface of equipment vs. heat input rate.

(2.2.3) Temperature rise of critical equipment elements and surface of package vs. time and heat input with stated ambient temperature and air velocity conditions.

(2.2.4) Life of critical elements vs. temperature of elements or package surface.

(2.2.5) Envelope dimensions, location and dimensions of any special heat-transfer fins, and color and type of surface finish.

(2.2.6) Provisions for attachment of accessory to aircraft.

(2.2.7) Quantity of air required for pressurization of equipment in pounds per minute vs. altitude and required internal pressure.

(2.3) For the type of package noted in (1.3), cooling requirements should include:

(2.3.1) Heat input and required heat dissipation rate in watts or B.t.u. per hour. See also paragraphs (2.1.1.1) and (2.1.1.2).

(2.3.2) Minimum required flow rate and maximum permissible temperature of cooling air into the package vs. various stated ambient temperature conditions of air and surrounding surfaces; all the above vs. altitude and heat input rate.

(2.3.3) Anticipated maximum exit air temperatures corresponding to inflow conditions noted.

(2.3.4) Pressure loss of cooling air flowing through package vs. cooling air flow rate and density. (Note that package pressure losses greater than 1.0 lb. per sq. in. at sea level or 0.1 lb. per sq. in. at 60,000 ft. would cost considerably extra weight and/or design complica-

* The term "boxes" as used here includes motor, generator, or solenoid outer cases if such equipment is considered by itself for cooling purposes.

† Temperatures used for determination of rate of temperature rise or length of element life should be readily measurable with standard instrumentation applied in the field.

(*Continued on page 67*)

## *The Basis for Compromise Between*

# Theoretical Performance and Operational Reliability

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*Stanford Research Institute*

### (I) Introduction

During the past few years there has been a tendency toward complexity in aviation electronics. Frequently it is heard that the new, more complex equipment is not worth while in view of some field conditions. With admitted simplification, the purpose of this presentation is to set forth some of the parameters an engineer should consider in putting this controversy on a factual basis. Actually, it is an operations research problem, and no one answer will satisfy more than one very special set of equipment and conditions.

### (II) Theoretical Performance

From an engineering point of view there is some maximum level of performance which can be expected from an ensemble of components. We may say, for example, that the sensitivity of a receiver is within 12 db. of the thermal noise level. We might accomplish this with perhaps 40 components. With more patience, as well as more components, we might achieve a figure of merit of 9 db. With still more components, and some stretching of time, we might perform some autocorrelation and actually penetrate the thermal noise barrier.

All of this is to illustrate the initial premise that for each function that we perform, we can, in theory, get an output performance proportional to the complexity. An example is drawn in Fig. 1. Our curve might be for a radar system and the performance measured in some units like yards of range against a target the size of a fighter plane. Below some modest number of components there is no radar and no radar performance. If the number of components is increased, one suddenly achieves a very simple radar. This may be akin to a proximity fuse or a superregenerative receiver.

As we increase the number of components we can increase sensitivity, gain, power, or whatever parameters may enhance our cause. A point is soon reached, however, where we cannot get any more sensitivity, and maybe we are radiating all the power the atmosphere can tolerate. Our increasing complexity then adds refinements that increase performance under only some conditions. These are exemplified by automatic gain and frequency controls, variable pulse widths and repetition rates, special time constants in the indicator circuits, and many others. The basic point is that, assuming no inventions or alternate modes of operation, performance as a function of complexity approaches some limit, $P_{max.}$, as shown in Fig. 1.

### (III) Mean Failure Interval

Turning to the practical side, experience has shown that certain types of components used in a given environment have rates of failure which can be predicted on a statistical basis. We might say, for example, that, for each ensemble of a vacuum tube and its immediately related components, there will be on the average one failure during each 5,000 hours of operation. If we have two tubes and their related parts, a failure may be expected on an average of every 2,500 hours. If we have a complex system containing 5,000 tubes, we shall average one failure every hour. The fact that the mean failure interval reduces to one-half each time the number of components doubles is shown in Fig. 2. This curve applies whenever we refer to equipments

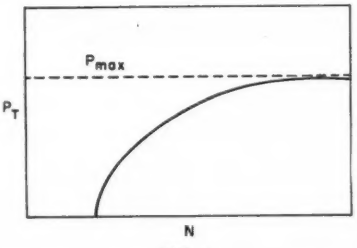


FIG. 1
THE GENERAL CASE OF THEORETICAL SYSTEM PERFORMANCE AS A FUNCTION OF COMPLEXITY

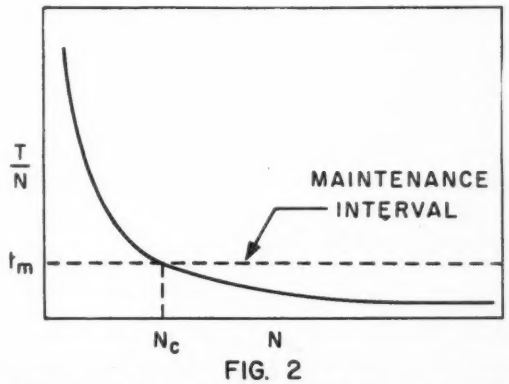


FIG. 2
AVERAGE FAILURE INTERVAL AS A FUNCTION OF COMPLEXITY

Presented at the Electronics & Aircraft Electrical Systems Session, National Summer Meeting, IAS, Los Angeles, June 21-24, 1954.

* Head, Equipment Engineering.

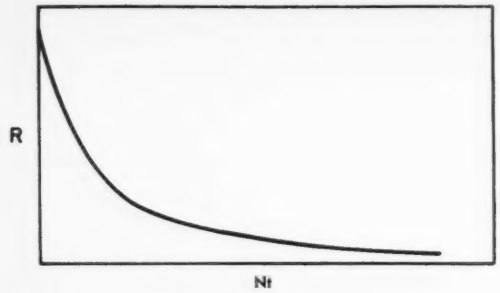


FIG. 3
RELIABILITY AS A FUNCTION OF COMPLEXITY AND TIME

that have been in use several hundred hours, have more than about five tubes, and are subjected to corrective maintenance only.

### (IV) Mean Maintenance Interval

Before leaving Fig. 2 the role of maintenance should be discussed. Suppose we have a system of 500 vacuum tubes which is carried in an airplane. Let us further suppose that this plane is out of the reach of skilled maintenance personnel for periods of 20 hours. On the average, we should expect one failure every 10 hours. This means our plane will accumulate an average of two failures somewhere in the electronic equipment during its mission. The question is, "How do failures in a system affect system performance?"

### (V) Reliability vs. Time

Here, again, we must resort to a simplification. Suppose all of the components in our system are vital, that is, the failure of any one of them would cause a failure of the system. Then the concept of an index of reliability which decreases with time, as developed by Dr. Carhart of RAND, applies. Fig. 3 shows the curve of system reliability as a function of time. This may be better understood by expressing its significance in several different ways. First, it means that if we have a large number of 500-tube systems, only $1/e$ or 37 per cent of the systems will remain in serviceable condition when the mean failure interval is reached. Second it means that a constant percentage of the remaining components can be expected to fail during any one time interval. Third, the function is equally dependent upon time and complexity. Finally, we must remember that it is a curve of probability, being true for a large number of systems but not categorically applying to one particular system.

### (VI) Probable Performance

The Carhart index of reliability shows that the probable performance of the equipment decreases exponentially with both complexity and time. If we first consider the time as a constant, the decreasing index of reliability with complexity will modify our original performance-vs.-complexity curve to the general shape shown in Fig. 4. We also note that the shape of this curve is not too dependent upon our original theoretical performance vs. complexity, since the curve tends to zero at larger complexities because of the Carhart function.

For any one system the curve of Fig. 4 must vary with time, again following the exponential decay. Thus, in reality, there will be a family of these curves that fit under that shown.

Thus far our curve of performance is incomplete in that at no point does it reach a negative value. In operations research it should be presumed that at some point of complexity the equipment could become a liability, and we have not yet indicated how this might be introduced into our performance curve.

### (VII) The Liability Function

In the various parameters discussed thus far, none of the drawbacks of complexity has been put on the debit side of the equipment. With increasing complexity there will be additional weight, fuel, spare parts, and power as well as higher man-power and supporting costs. These factors can be termed liabilities, and, in general, will increase with complexity. Without being specific about the function, let us assume for illustrative purposes that this liability factor increases linearly with complexity, being zero with zero complexity.

From an operation point of view, this liability or probable cost of supporting this number of components must be subtracted from the probable performance that might be expected. Thus, our curve of Fig. 4 is only the positive, or the performance-at-any-cost, part of the picture. When the liability factor is subtracted from this we get a curve that actually crosses the zero performance line at some complexity. This idea is shown in Fig. 5.

Some speculation is in order as to what constitutes this crossover point in a given system. Suppose a Loran receiver-indicator contains 60 vacuum tubes. Assuming 5,000 tube-hours per failure, the average failure interval is 5,000/60 or about 83 hours per set. If a military commander wants to send a group of bombers on a 20-hour mission, the exponential law of Car-

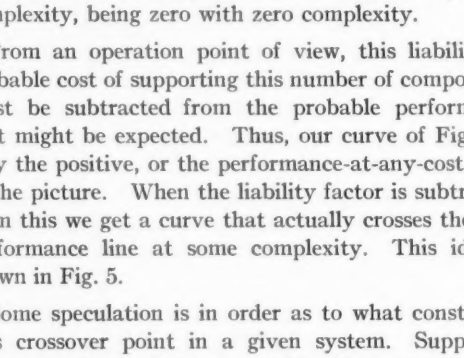


FIG. 4
SYSTEM PERFORMANCE IN THE FIELD COMPROMISED BY PROBABLE RELIABILITY

hart would give an index of reliability of $e^{-(20/83)}$ or 0.78. Roughly, this means that at least one plane in five should be without Loran, or, on a single plane, the chances are less than four out of five that the Loran would be working.

To achieve these figures, the group must be in working order at the start, and the degree of preventive maintenance must hold the equipment to the 5,000 tube-hour per failure average. With a bomber squadron of 16 planes, the maintenance crew must be able to repair, among other things, an average of three Loran sets between each mission. If the maintenance facilities are inadequate, there is a lack of spare parts or extra personnel when there might be four or five sets in need of repair; then the total failures are increasing faster than they are corrected by maintenance. Sets in this condition rapidly become dummy loads for technological man power and serve no useful purpose.

A military commander might look at the problem another way. He may have to train 20 skilled people to maintain and operate this equipment. In return he gets certain information or does certain damage to his opponent. The payoff must be answered in terms of cost not related to our immediate equipment. This, perhaps, is the most disconcerting thing an electronics engineer faces in trying to evaluate the worth of his equipment.

### (VIII) Conclusions

To summarize, then, it is possible to make curves for probable performance in the field based on presently available statistics of failure rates. It is also possible for the user of electronic equipment to determine the probability that his equipment will perform under certain conditions, in a certain complexity, and for a certain length of time. The final answer, however, does not rest with the designer of a specific equipment since the field performance to the user of the equipment will depend on the complexity of this equipment, with alternate solutions to the same problem.

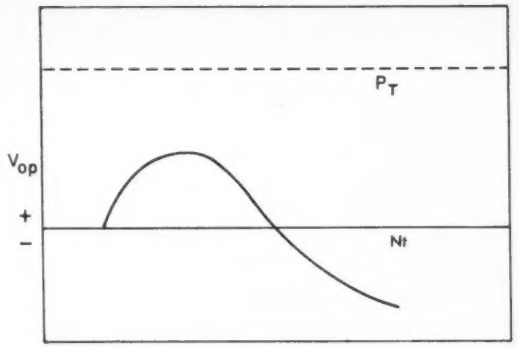


FIG. 5
OPERATIONAL VALUE OF A SYSTEM AS A FUNCTION OF COMPLEXITY

It is also essential to realize that because performance of any one system is a matter of probability, the question of the type frequently raised in the press—as to whether or not radar should be substituted for a wad of chewing gum on the canopy of a fighter plane—cannot be answered at the equipment or the fighter-pilot level. Whether there is a payoff that can justify the use of the equipment in the field must be decided at a higher level.

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## Thermal Considerations in Electrical Accessory Design (*Continued from page 64*)

tion in the equipment cooling systems of high-performance military aircraft now under construction at Douglas El Segundo. Therefore, packages with high cooling air pressure losses should offer decided advantages in weight-savings or advanced performance over those with lower pressure losses. However, it should be remembered the convection heat-transfer rate is proportional to the heat exchanger pressure drop; therefore, pressure drop should be as high as possible compatible with the above limitations.)

(2.3.5) Temperature rise of critical accessory elements vs. time and heat input with no cooling air and with specified quantities of cooling air.

(2.3.6) Life of critical elements vs. temperature of elements.

(2.3.7) Envelope dimensions and color and type of surface finish.

(2.3.8) Location and size of the inlet and outlet fitting for cooling air. Also, means provided for attaching inlet and outlet ducting to be provided by air-frame manufacturer.

(2.3.9) Location and performance vs. altitude of any internal fans.

(2.3.10) Provisions for attachment of equipment to aircraft.

(2.3.11) Layout of heat-transfer surfaces in package and mean operating temperature of these surfaces if these data are available.

(2.3.12) Quantity of air required for pressurization of accessory in pounds per minute vs. altitude and the required pressure.

(3.0) Accurate obtainment of the above data calls for a considerable knowledge of heat transfer and air flow. It is recognized that such data may not always be readily available to many electrical designers. Two valuable publications that will assist greatly in providing such knowledge are:

(a) *A Design Manual for Determining the Thermal Characteristics of High Speed Aircraft*, Air Force Technical Report No. 5632, September, 1947.

(b) *The Thermal Evaluation of Air Cooled Electronic Equipment*, Air Force Technical Report No. 6579, September, 1952.

In the latter report special attention was paid to writing in a manner readily understandable to electrical and electronic engineers.

# Aeronautical Research and Development in Sweden

## *Financial Background and Organization*

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SUMMARY

Sweden's defense expenditure is given in per cent of the state's total expenditure and of the gross national product and in comparison with the figures for some other countries. Headlines from Swedish aviation history and facts of importance to the development of the Swedish aircraft industry are indicated. The principal lines and goals for aeronautical research are given, as well as a short description of the participating institutions and facilities available. Planning of the work and cooperation among the institutions are described and exemplified.

### INTRODUCTION

AN AMERICAN AUTHOR has coined the phrase "Sweden, the middle way" as a kind of heading for our way of living in Sweden. This phrase is apt: Sweden is a monarchy but at the same time a very well-developed democracy; the main part of the Swedish national income is divided between the Armed Forces and the social welfare program; most of what happens in the political and social life, as well as to the individual Swede, might be compared to an oscillation of a strongly damped system with a fairly long period.

The social welfare program has asked for a successively increasing part of the Swede's income. At the same time, however, he has felt it necessary and very worth while to keep the Swedish neutrality well armed. The expenditure for defense is today about the same as, but slightly less than, the expenditure for the social welfare program.

### DEFENSE EXPENDITURE

According to available official acts,[1] Sweden's expenditure for defense—relative to the state's total expenditure—mounted to 50–60 per cent during World War II, dropped to 25 per cent during the fiscal year 1945–1946, passed a minimum of about 19 per cent during the period 1947–1950, to increase again slowly to nearly 26 per cent for the fiscal year 1953–1954. Compared to the total income of the state—the gross national product—the total defense expenditure was about 11 per cent during the war, 3–4 per cent during the period 1946–1951, and 5 per cent for the fiscal year 1953–1954.

Available international data[2] give the figures comparable to Sweden's 5 per cent of GNP as 12 per cent for the United Kingdom, 13.1 per cent for the United States, and 9.6 per cent for the European NATO powers taken together (all figures for 1953–1954). The present figure for Sweden is apparently relatively small and means that the Swede sacrifices less of his living standard for defense than the inhabitants of the other countries mentioned. Regarding the absolute value of the sum, one should note, however, that the Swedish national income per individual is considerably higher (the highest in Europe, Switzerland being very close to it) than the mean value for the European NATO powers. A comparison shows that 5 per cent for Sweden and 9.6 per cent for the NATO powers give almost exactly the same amount of money per individual, or $58. The 12 per cent for U.K. compares to 102 defense dollars per individual, and the 13.1 per cent for U.S.A. to 297.

The share of the Royal Swedish Air Force in the total defense expenditure has for some years been about 34 per cent.

### AVIATION HISTORY

The history of aviation in Sweden is quite naturally closely connected to that of the Royal Swedish Air Force. Some headlines may be of interest:

*1925*—looked upon as the year of birth of the independent Swedish Air Force, which was given, however, very small financial grants.

*1936*—the Riksdag decided upon a substantial expansion of the Air Force, planned to be completed within 7 years.

*1940*—the basis was created for an expansion of the Swedish private aircraft industry, aiming at a self-supporting industry, through the so-called basic agreement between the government and industry which secures to the latter a certain degree of employment during a certain number of years.

*1942*—the Riksdag approved the defense plan that gave Sweden its Air Force of today. Certain additions have been made by the Riksdags of 1947, 1948, and 1949.

Fom many points of view it has been extremely valuable that the Swedish Armed Forces, and especially the Air Force, have been allowed to develop in a continuous and quiet way. In comparison with the situation in many other countries there is a main difference in development line which should be pointed out: The entire Swedish Air Force is under one single command—there are no separate Army or Navy Air Forces. Furthermore, there are two factors that should be stressed as being of the greatest importance to both the Air Force and the aircraft industry: first, the security that was

Presented at the Seminar on Wind-Tunnel Techniques and Aerodynamics in Stockholm, May 10–11, 1954.

* Head, Technical Analysis Department.

created for the aircraft industry with the aforementioned basic agreement; second, and above all, that every year, at the same time that the grant for the year is approved by the Riksdag, a long-term program is also approved for the purchase of aircraft and related equipment for the following 7-year period. Some figures for these 7-year programs are:[3]

1948–1949, 1.074 million crowns
1950–1951, 1.227 million crowns
1952–1953, 1.771 million crowns
1953–1954, 2.105 million crowns
1954–1955, 3.150 million crowns

The increase from 1948–1949 to 1954–1955 is high even if the price increase during 1951 and 1952 is taken into account. The increase in current prices is 293 per cent and 230 per cent if the budget from 1948–1949 is reduced to the prices of 1952 with the general consumer price index.

As mentioned above, the basis for an independent Swedish aeronautical activity of greater importance was created during the early part of the Forties. The development may be illustrated by the different types of aircraft produced since 1940 by Svenska Aeroplan Aktiebolaget (SAAB), in Linköping and Trollhättan, and the year for the first prototype flight (see Figs. 1–9). They include six military-service aircraft types, each with different versions; two civilian aircraft types; and three research aircraft, of which only the latest—SAAB 210 Draken—is shown, the other two being SAAB Safirs for low-speed research with wings of the same plan form as that of the 29- and 32-types.

While SAAB is the only Swedish aircraft industry of any importance, Svenska Flygmotor Aktiebolaget in Trollhättan plays the same role for aircraft engines. The engines for the SAAB aircraft in their production models have all been built under license by Flygmotor, with the exception of the civilian types.

## Principal Lines for Aeronautical Research in Sweden

During this period of expansion and development, of which the first years coincided with World War II, we have only to a comparatively small degree had the opportunity to get information on experiences and results of research in other countries. This is, of course, dependent upon the fact that Sweden by old tradition is alliance-free and so outside the NATO powers. To be able to create and maintain an independent Air Force we had to erect a mainly self-supporting organization for aeronautical research and development. The limited financial resources of the country made it imperative to relinquish broad and basic research and to economize by *conducting the work always against goals as well defined as possible* and, further, to make full use of the advantages of Sweden's being a small country—i.e., by carefully *coordinating all resources* of the country in efficient work *for the joint goal.* This has succeeded 100 per cent in many fields, for instance, in developing wind-tunnel capacity.

The principal goals for our aeronautical research and development have been the following:

(1) We have to be self-supporting in such theoretical development work that is required for our own special circumstances and within such fields where it obviously, often due to military secrecy, would be difficult to "purchase" knowledge from abroad.

The reason for this is obvious: If one urgently needs something that is not available, one has to produce it oneself in one way or another.

(2) Our level of knowledge must be so high that we are able to make good use of the know-how and equipment that *are* available.

Foreign research institutions normally will publish only such basic work that is so general in character that the real cause of the work cannot be assumed to be evident. If, however, one is doing qualified work in the same field oneself, even a report on such a basic work—often the very publishing of it—can be of great value. Furthermore, it may bring up new ideas and other ways to tackle the problem under consideration.

Concerning equipment, it is of course always a question of knowing exactly the need before one can buy, and for this qualified knowledge is very often required.

(3) Our level of knowledge must be so high that it will assure us of goodwill great enough to allow the purchase of knowledge, services, and goods of high quality.

As an example, it might be recalled that when a very promising development on aircraft engines within this country for various reasons had to be interrupted, the Air Force succeeded in purchasing the license for a first-class engine from abroad. The result is certainly not likely to have been the same if we had not ourselves had a first-class engine ready for production.

## Institutions and Facilities

With the program mentioned above for the expansion of the Swedish Air Force and the indicated limitations of the research work as a background, Sweden's resources for aeronautical research and development have been planned and successively built up. In addition, the Air Force (the Royal Air Board) has been taking part in the development program in the best collaboration with the institutions concerned.

Today there are mainly eight institutions participating directly and with a high percentage of their capacity in aeronautical research and development.

*Under the command of the Chief of the Royal Air Board are:*

(1) Försökscentralen, the Experimental Center of the Royal Air Board, for flight testing and development of aircraft, engines, armament, and equipment.

(2) Robotvapenbyrån, the Guided Missiles Department, for development work on guided missiles.

*Directly connected to the Defense Department is:*

(3) Försvarets Forskningsanstalt, the Research Institute of the Armed Forces, with different departments for chemical, physical, and electronic research and development.

FIG. 1. SAAB-17, 1940. Dive bomber and reconnaissance aircraft. Available with wheel-, ski-, and float-undercarriage, the former two retractable. Engine: Pratt & Whitney R-1830.

FIG. 2. SAAB-18, 1942. Dive bomber and long-range reconnaissance aircraft. Engines: Pratt & Whitney R-1830 and for later versions Daimler-Benz DB 605 B.

FIG. 3. SAAB-21, 1943. Fighter, first aircraft with a pilot's ejection seat of Swedish design. Engine: DB 605 B.

FIG. 4. SAAB-91 Safir, 1945. Three to four seat light plane. SAAB-91B now used as the Swedish Air Force's standard primary trainer, Air Force designation Sk 50. Engine: de Havilland Gipsy Major and, for later versions, Lycoming O–435 A.

FIG. 5. SAAB-90 Scandia, 1946. Medium transport for 32 passengers. Engines: Pratt & Whitney R-2180.

FIG. 6. SAAB-21R, 1947. Sweden's first jet fighter, a development of the SAAB-21 pusher fighter. Engine: de Havilland Goblin.

*To the Trade Department belongs:*

(4) Flygtekniska Försöksanstalten (FFA), the Aeronautical Research Institute. The first grant for the erection of FFA was made by the Riksdag in 1937, and offices, workshops, and laboratories were ready in 1940. The first wind tunnel, the 3.6-meter circular section low-speed tunnel, was completed during the spring of 1941. Since then the FFA has expanded steadily.

To the Institute's aerodynamic facilities belong the low-speed tunnel mentioned above, one continuous flow tunnel with a circular test section of 1 meter for Mach Numbers up to 0.92, and one intermittent flow trans- and supersonic tunnel with a test section of 1 sq. meter, driven by a vacuum rock chamber. There are also several smaller supersonic and other tunnels.

The institute is fairly well equipped for structural research. There are facilities for strength tests of complete aircraft structures as well as for static and fatigue tests of elements of different sizes.

The ever-increasing demand for all different kinds of measuring equipment is fulfilled by the Physics Department, which obviously has to do its own research and development work in this field. Moreover, it should be mentioned that the workshops are provided with modern facilities for the construction of models, test specimens, and measuring devices.

*The only university in Sweden that does research work in aeronautics is:*

(5) Kungliga Tekniska Högskolan (KTH), the Royal Institute of Technology, in Stockholm.

Until about 1945, the Aerodynamics Laboratory of the Division of Aeronautics at KTH served mainly as an exercise lab for the students, with an open-throat, low-speed tunnel of the Göttingen type as the main equipment. Since 1945 the Laboratory has extended its activities very rapidly. The low-speed tunnel has been modernized, and new equipment of different kinds have been designed and built, as supersonic and other tunnels, electric analogs, etc. A high-quality scientific staff has been created and the whole unit has proved to be of the greatest value to Swedish aviation. The expansion has to a great extent been financed by contract work for the Air Force, directly or via SAAB.

As the other more "normal" institutions for aeronautical research and development are reaching their planned capacity, the contract work at the Aero Lab is decreasing slowly leaving more opportunity for fundamental research and the training of students, now in a well-equipped and modern laboratory.

The Structures Department of the Aeronautics Division is also doing research and development work on Air Force contract. This department is only a few years old and has a rather limited capacity for such work. The investigations carried out so far have been of a theoretical-numerical character, in some cases in connection with experimental studies on analogs in the form of perspex structures. A laboratory is planned but not yet established.

FIG. 7. SAAB-29, 1948. Swept-wing jet fighter, attack and reconnaissance aircraft. Engine: de Havilland Ghost. New version has Swedish afterburner.

New facilities are planned at KTH for the whole Aeronautics Division.

*The three remaining institutions are all within private industry:*

(6) The well-known Bofors Co. is continuously doing research and development work in most areas of the large field of armament and artillery. Recently Bofors equipment for ballistic research was extended with a 150-atmosphere 650°C. blow-down supersonic wind tunnel.

(7) Flygmotor, the aircraft engine manufacturer, has well-planned and modern facilities for all kinds of research in the engine field as well as high-pressure wind tunnels suited for research on air intakes, flutter and ballistics. The 8.5-atmosphere air supply to all the test facilities is fed from a unique underground rock chamber where the air is kept under constant pressure with the help of a waterspout from the adjacent river. The largest wind tunnel has a test section of 0.5 by 0.5 sq. meters and covers a range of Mach Number from 0.7 to 3.6, including the transonic range.

(8) Within SAAB research and development work is going on continuously which covers in one way or another the entire aeronautical field: The whole line from the raw material used, through design and production methods, to the highly developed aircraft equipment, as well as from project studies, through methods and means for analysis, to the use and tactics of the complete product.

In those fields where SAAB is not doing research of its own, it is felt necessary to have personnel who are able to follow up what is being done outside the firm and so to understand and evaluate this and predict the future development.

The work is not hidden in a separate research department but is going on hand in hand with the work on the actual designs. The intention is, of course, to keep the research and development on sound lines and to make it easier to "sell" the results of it within the firm.

It seems a little outside the scope of this paper to try to list the different items of equipment for research and development available at SAAB. It might be men-

FIG. 8. SAAB-210 Draken, 1951. Delta-wing low-speed research aircraft. Engine: Armstrong Siddeley Adder.

tioned, however, that this equipment includes a four-jet-engine-powered ejector tunnel of 0.7–0.5 sq. meters, covering $M = 0.5$–transonic–1.5, and a good set of both digital and analog computing machines.

## PLANNING

The general program for aeronautical research and development concerning military aviation is outlined and implemented by the Royal Air Board in cooperation with the aeronautical industries. This is accomplished in a form of good teamwork, with the initiative coming from either side, which might be possible only in a small country like Sweden.

As an aid in keeping the research work within economically reasonable limits the general program is divided into subprograms spanning a shorter period of time and with successively decreasing range. Two types of such subprograms are of special interest.

One subprogram is worked out by aircraft type and covers all the work (at least in outline) which has to be conducted before the real project work on a new aircraft type can be started. It includes investigations of all the different kinds of armament and equipment to be used as well as economic and military-tactical aspects of the whole anticipated unit, handled with operational analysis. Furthermore, there is indicated the institution or person responsible for every part of the program.

The other program sums up all the research and development work within one field—all participating institutions included—which is planned for a period limited to half a year. It follows that this program is rewritten twice a year; also incompleted investigations are included to give a full picture. A detailed time schedule is attached, for instance for all wind tunnels in the country.

The "type research program," as well as certain of the "half-year programs," is outlined by the institution that primarily needs the program for its work (for example, SAAB for the half-year program for aerodynamics and structures). The programs are then discussed very carefully with the Royal Air Board as well as with the other institutions concerned, after which a revised, and by all parties approved, final edition is given out.

In other countries larger than Sweden, this procedure would probably be difficult and slow-starting, but here it has turned out to be both fast and flexible. That it does function well depends to a very high degree on the good contacts, often of a personal kind, which exist between the co-working members.

## EXAMPLE OF FUNCTIONING

To show how a single investigation included in a half-year program is carried out, a wind-tunnel test is chosen as an example. The problem that has to be solved quite naturally in general will come up at SAAB. The course of events, in chronological order, is about as follows:

The problem is pinpointed and carefully defined by the aerodynamicist working with it and then passed to a special test group within the Aerodynamics Department. This test group will manage the work in the following manner:

The test program is worked out in detail. In the final program there is given, besides the measuring program itself, the purpose of the test. Also, the method to be used is often proposed and how the results shall be reported.

The wind-tunnel models required for the test are designed. These can be made within the special test group or by the design group that is available at most of the wind-tunnel institutions. At the same time, required measuring equipment, built-in balances, etc., are designed.

The manufacturing of models and balances is ordered. For this work, too, there are different skilled workshops

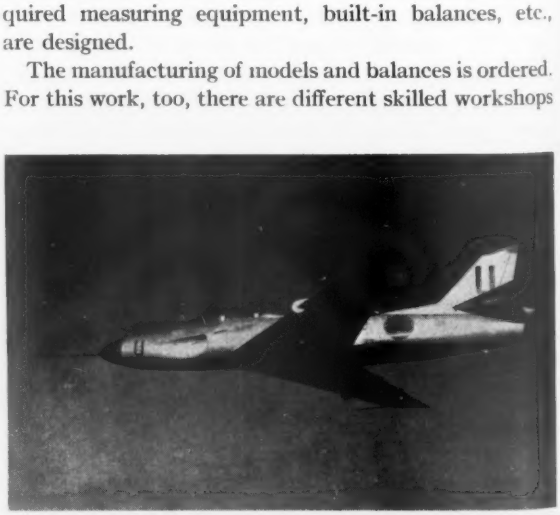

FIG. 9. SAAB-32, 1952. Two-seat, all-weather jet attack aircraft. Also to be built for night fighting and reconnaissance. Engine: Rolls-Royce Avon.

available. As far as possible, the capacity within SAAB or the other wind-tunnel institutions is used.

The wind-tunnel test is carried out by the personnel at the actual wind tunnel according to the program worked out by the ordering institution. Of course, the program might be modified or increased during the test, often on the proposal of the wind-tunnel staff. The results are reported first in a preliminary form and then, when the test is completed, in a report that—beyond the test results in numerical and graphical form—contains only the data necessary for the customer when he studies the results.

The analysis of the results up to "the answer upon the question" is not made by the wind-tunnel staff but by the ordering institution. The special test group within the Aerodynamics Department at SAAB refines the results to the form, derivatives, etc., required by the aerodynamicist. The latter will finish the process with an analysis, for instance a comparison with theoretical calculations.

To the administrative part of the procedure, which falls to SAAB, belong the *time planning* of the design and construction of models and the test itself, formal *ordering* of the different phases, an *estimating of the cost,* and, furthermore, a continuous *following-up* of the time schedule as well as the cost. The costs are in most cases booked on what could be called the preproduction cost for a certain aircraft type—i.e., the cost for research, project work, engineering, design, etc., for a new aircraft type. The invoiced costs from the governmental institutions are collected on a special account. Through an agreement they shall be excluded from that part of the costs on which SAAB is allowed to make profit.

It should be emphasized that we do not have in Sweden, compared with the situation for instance in England, any large governmental institution such as the English Royal Aircraft Establishment to which the aircraft industry can hand over a problem and, after a certain time, receive an analyzed answer. In our case, the work for the aircraft industry, performed within another institution, as a rule is initiated and, to a certain extent, conducted by the aircraft industry with a very close contact between the participating members. It is not improbable that this latter procedure is more efficient.

Another course of events is used now and then and ought to be noted. Any one of the institutions may find during its work a new problem that it would like to study or in which further investigation would give a much better and clearer view of a field already partly investigated. This institution then will outline a program that is presented to one or more of the other interested parties. If the agreement is reached that the investigation is worth while and that space is available, the appropriate institution can authorize the initiator to undertake the study.

Quite naturally the different members of the team also have opportunities to do research work according to their own will. FFA, for instance, every year has a grant that makes it possible to reserve about one third of its total capacity for private research.

## Concluding Remarks

The governmental authorities of different kinds, who in the large nations coordinate the research in different fields, are almost totally lacking in Sweden. This certainly has its consequences. Properly used and with the right personnel, such authorities should make it easier for different demands to make themselves heard and should be the right tools for the government to analyze and grade these demands.

In the aeronautical field, however, this lack has not caused any serious trouble in Sweden up to now. Our resources and our political situation have left as the only choice an effective use of available opportunities. We cannot afford to make big mistakes, nor can we prevent mistakes by trying parallel or different alternatives in order to be able to choose the best one in the end.

Is there too much "utility" and too little "academic freedom" in aeronautical research in Sweden? The question is open, but the author's personal opinion is that we *have* to choose, that we have chosen the right compromise, and that we have lost very little if anything in taking the utility way. Using modern terminology, our way is the result of "system-thinking" applied to aeronautical research and development in a small country that has decided to have a strong Air Force, but which has a limited supply of both money and scientific staff.

## References

[1] Kontakt med krigsmakten, nr 2–3, 1953.

[2] Kontakt med krigsmakten, nr 4, 1954. Origin: The mutual security program for fiscal year 1954, June, 1954; *OEEC Annual Review,* 1953; *ECE Economic Survey of Europe Since the War,* 1953.

[3] Statsverkspropositionen: Bil. 6: Fjärde huvudtiteln: Flygvapnet.

# IAS News

(*Continued from page 39*)

**Arnold Rosenberg** (AM), Staff Assistant to the President, General Precision Equipment Corporation. Formerly, Assistant Vice-President—Operations, Kearfott Company, Inc.

**Laddie L. Stahl** (M), Manager, Product Planning, Guided Missiles Department, General Electric Company. Formerly, Lieutenant Colonel, USA, Army Plans Division, G-3.

**Richard E. Stockwell** (AM), Editorial Director, American Aviation Publications. Formerly, Editor, *Monsanto Magazine*, Monsanto Chemical Company.

**George B. Thorp** (AF), with Carnegie Institute of Technology. Formerly, Engineer, Trans-Sonics, Inc.

**John R. Westell** (TM), Aerodynamicist, Joy Manufacturing Company. Formerly, Design Engineer, Special Products Section, Electronics Division, Canadian Westinghouse Electric Corporation.

**Gerald B. Wright** (M), Assistant Manager for Research and Development, Air Force Department, Sperry Gyroscope Company Division of The Sperry Corporation. Formerly, Sales Representative, Sperry Gyroscope.

**Dr. Yusuf A. Yoler** (TM), with Harvard Business School, Harvard University. Formerly, Post-Doctoral Research Fellow, California Institute of Technology.

# Corporate Member News

• **Aeronca Manufacturing Corporation.** . . It was reported that Aeronca has completed a full-scale mock-up of a high-wing twin-engined business aircraft design. Designated the Aeronca 19, this aircraft reportedly is of all-metal construction and is designed to carry eight to ten passengers and to travel over 300 m.p.h. The estimated cost of the Aeronca 19 is given as $350,000.

• **Air Associates, Inc.** . . . A pneumatic pressure regulator valve, known as the HC-5616, has been designed by company engineers "to restore the instinct-guiding 'feel' in the power rudder control system" of Convair's F-102. This valve is 8 in. in diameter and 7 in. in length.

• **AiResearch Manufacturing Company, a Division of The Garrett Corporation** . . . An engineering folio that describes air data components and systems for aircraft and guided missiles has been published by AiResearch. This 26-page booklet outlines transducers measuring pressure ratio, air-stream direction, total temperature, vertical or horizontal accelerations, static pressure, differential pressure, incremental pressure, and vertical velocity. Computers described use this data to supply true angles of attack and yaw, free air-stream static temperature, velocity of sound propagation, absolute air density at flight altitude, true air speed, dynamic pressure, rocket and missile jump angle, and ballistics of projectiles. Copies may be obtained upon request from the company's Los Angeles office.

• **Aluminum Company of America** . . . The development of a high-strength aluminum forging alloy that has been perfected by Alcoa to meet the needs of modern aircraft has been announced. Known as X7079, this new alloy is said to offer aircraft designers aluminum forgings with greater uniformity of properties in heavy sections and a considerable increase in ductility in cross-grained directions. The production of X7079, a member of the aluminum, zinc, magnesium, copper series of alloys, will be limited at the present time to forging applications for which it was developed. Attention is being directed, however, toward its possible use in other wrought aluminum products, such as heavy plate and extruded sections.

• **Bell Aircraft Corporation** . . . The company reports that its new three-place production helicopter, the Model 47H, will be ready for market shortly after the first of the year. The 47H is intended primarily for the executive transport and passenger market; however, it is designed to accommodate most utility kit installations and float gear for amphibious operations.

• **The Bristol Aeroplane Company of Canada Limited** . . . The preliminary details of the BE 25 supercharged turboprop power plant, developed by The Bristol Aeroplane Company's Engine Division in England for transport aircraft operation, have been announced. The BE 25 is rated at 4,000 hp.; this power, the company says, remains constant from sea level to cruising altitudes and "therefore has available full power for take-off from any aerodrome in the world." This BE 25 project was originally initiated as a private company venture but has since been given a British Ministry of Supply contract. . . . The corporate trade style of Bristol Aeroplane Engines (Western) Ltd. has been changed to Bristol Aero Engines (Western) Limited. It was announced several months ago that the name of Bristol Aeroplane Engines (Eastern) Ltd. had been changed to Bristol Aero Engines Ltd. (See AERONAUTICAL ENGINEERING REVIEW, page 76, August, 1954.)

• **The Cessna Aircraft Company** . . . An improved version of the Model L-19, designated the OE-2, will be used for observation and reconnaissance missions by the U.S. Marine Corps. This aircraft has a top speed of over 180 m.p.h. and is designed to operate from small unprepared front-line areas. The OE-2 is able to carry a 250-lb. bomb on each wing, three rockets, a telephone wire-laying container, a chemical spray tank for laying smoke screens, or an aerial delivery container for dropping supplies to ground troops. It is powered by a Continental Motors Corporation 265-hp. supercharged engine. The first of 25 OE-2's is scheduled to come off Cessna's production line in the fall of 1955. . . . The L-19 that phased out Cessna's production L-19 contract with the Government rolled off the company's line on October 7. This last production L-19 brought the total of production reconnaissance planes to 2,480.

• **Chance Vought Aircraft, Incorporated** . . . The 1954–1955 College Scholarship Program for the sons of Chance Vought employees has been announced. Following competitive tests, two scholarships will be awarded for the study of engineering or allied sciences at an accredited college or university offering a standard 4- or 5-year course leading to a bachelor's degree in those subjects. Each scholarship will provide full tuition and laboratory fees and, in addition, $500 a year. The winners will be free to select their own schools. This College Scholarship Program was established last year.

• **Curtiss-Wright Corporation** . . . The Electronics Division is building under a USAF contract "the nation's first turboprop simulator for the first U.S. turboprop transport—the Lockheed C-130." Curtiss-Wright has delivered or is making simulators for these other aircraft: Douglas DC-6B, Convair 340, and Boeing 377 commercial transports; Boeing B-52, Convair B-36, and Boeing B-50 bombers; McDonnell 2F9 jet fighter; and Douglas C-124, Fairchild C-119, and Boeing C-97 military transports.

• **Douglas Aircraft Company, Inc.** . . . The Chamber of Commerce and City Fathers of Santa Monica, Calif., presented a bronze plaque to Donald W. Douglas, IAS Honorary Fellow, Benefactor, and Founder Member and President of the company, and to 23 30-year employees on the thirtieth anniversary of the 1924 around-the-world flight. (These employees represent one fourth of the number of people employed by Douglas in 1924.) The plaque was presented by Mayor T. J. McDermott in recognition of this first circumaviation of the earth and succeeding aeronautical "firsts" by the company.

• **Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation** . . . It was announced on October 7 that the first two production models of the C-123B Avitruc assault transport to roll from Fairchild's final assembly lines have been delivered to the Air Force for further testing operations. The Avitruc is reportedly the first assault transport to be placed in service with the Air Force and has been classified as an assault transport because of its ability to land in or immediately after the initial military assault.

• **Fairchild Aircraft Division and Fairchild Engine Division, Fairchild Engine and Airplane Corporation** . . . A C-82 Packet equipped with an experimental turbojet power augmentation installation has been undergoing flight tests to determine the value of jet assistance in increasing take-off loads and rate of climb. The engine employed in these tests is the J-44, de-

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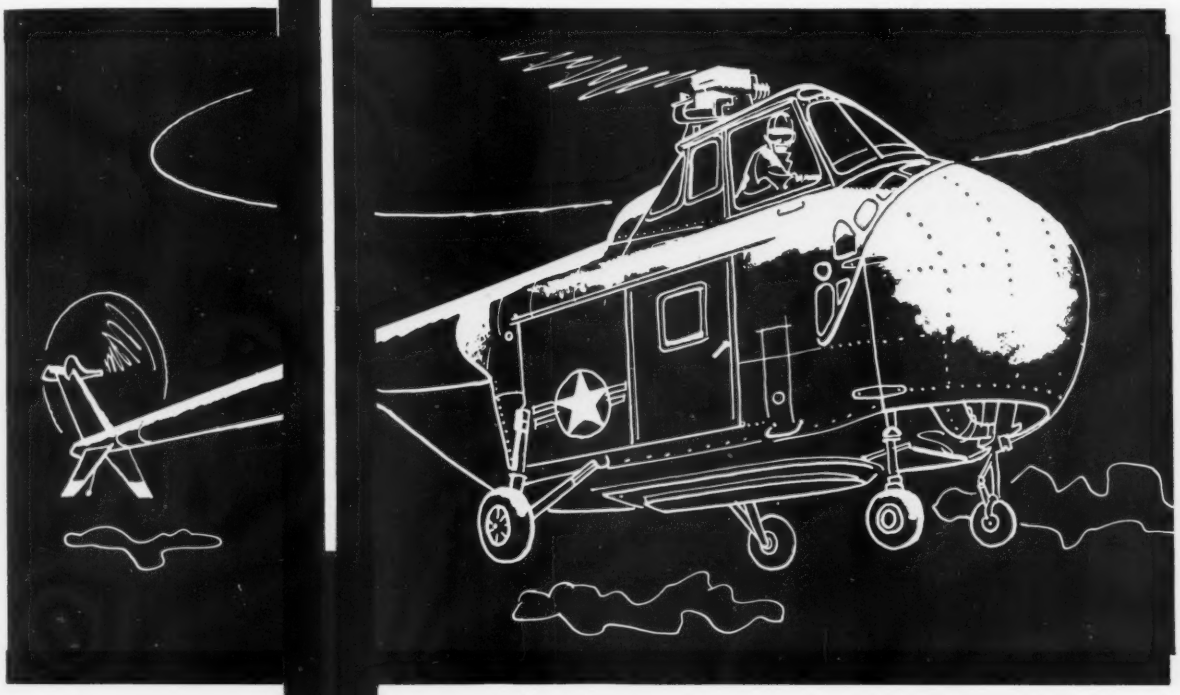

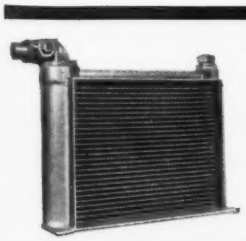

The 'copters are coming . . . and coming fast—*and Harrison keeps them cool!* Yes, the helicopter is growing up—with new "city-center" take-off and landing sites for short-haul passenger and cargo service—*and Harrison is keeping pace!* In fact, *Harrison cools practically every 'copter that's flying today . . .*: and there are good reasons for this outstanding leadership. Harrison oil coolers are designed to save weight and space, which are vital when you're carrying a payload. With our unexcelled research facilities, we're always looking for ways to make aircraft heat exchangers lighter, more dependable, more durable than ever. If you have a cooling problem, look to Harrison for the answer!

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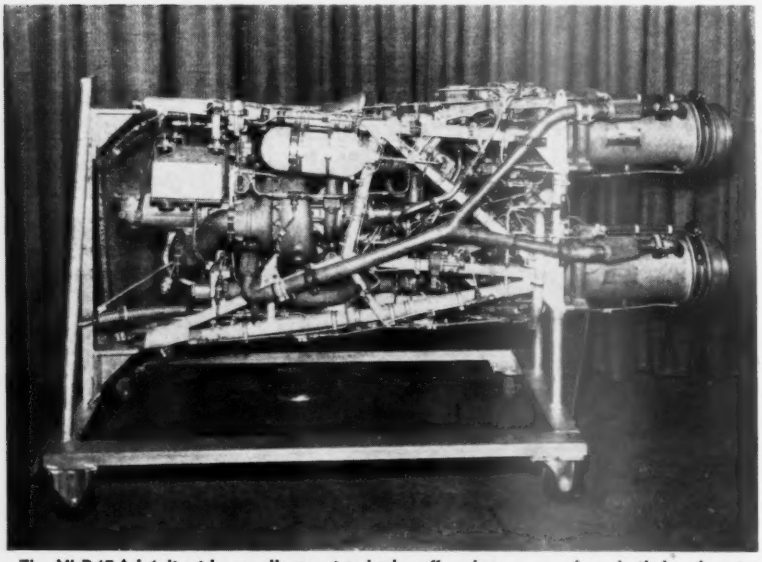

**The YLR45AJ-1 liquid-propellant assisted-take-off rocket power plant, built by Aerojet-General Corporation, Subsidiary of The General Tire & Rubber Company, is used in integral installation on the USAF B-47 bomber, manufactured by Boeing Airplane Company. This rocket power plant, which Aerojet recently demonstrated publicly for the first time, has undergone a flight-test program in a B-47. It was developed under the cognizance of WADC's Power Plant Laboratory, and its performance characteristics and design data are still covered by military security.**

signed and built by the Fairchild Engine Division for powering target drones and guided missiles. The J-44, which produces an additional 1,000 lbs. of thrust on take-off, is mounted on a fixed pylon atop the cargo fuselage.

• **Fairchild Camera & Instrument Corporation . . .** The recently announced Special 1:1 FPO Polaroid Oscilloscope Camera is a special Fairchild adaptation of the Polaroid-Land principle of a "photographic print in one minute." The company claims that it is the only unit available on the market today which is able to record phenomena from a 5-in. cathode tube at a 1:1 ratio on Polaroid-Land film. The camera is equipped with a 75 mm. f/1.9 Wollensak Oscilloanastigmat with a No. 3 Alphax shutter having speeds of 1 sec. to $^1/_{100}$ sec., time and bulb. Print area is 3 by 4 in.

• **Fletcher Aviation Corporation . . .** Pasadena-Rosemead Airport, owned by Fletcher and adjacent to the corporation's new 123,000-sq.ft. factory, has been renamed Fletcher Airport. The official address for Fletcher Aviation Corporation is now Fletcher Airport, Rosemead, Calif.

• **Flight Refueling, Inc. . . .** A 10-page booklet, "Flight Refueling, Inc. Moves Ahead," has been put out by the company.

• **G. M. Giannini & Company, Inc. . . .** A new low-cost infinite resolution slide wire "Spiralpot" has been put into production by the company. This is a $1^1/_2$-in. diameter potentiometer with a standard $^3/_8$-in. threaded bushing for panel mounting a locating pin. The unit can be used as a direct potentiometer replacement for applications requiring "stepless" potentiometer operation. . . . J. Murray Wilson has been elected Vice-President and Treasurer of the company, and Edward H. Hughes has been voted Assistant Secretary.

• **Harvey Machine Co., Inc. . . .** It was recently announced that Rear Adm. A. J. Wellings, USN (Ret.), had become associated with Harvey as Technical Consultant. Admiral Wellings, a 1919 United States Naval Academy graduate, retired from the Navy after 35 years of active duty.

• **Jack & Heintz, Inc. . . .** The development of a new air-cooled a.c. generator capable of operation at environmental temperatures as high as 120°C. has been announced. At the same time, Jack & Heintz reported that it had developed environment-free special-liquid vapor-cooled generator designs, whose cooling mediums are independent of the outside air conditions. . . . A new circuit breaker designed for use with the complete a.c. systems produced by Jack & Heintz for the aircraft industry has been developed. Designated type GC86, this new 4.5-lb. circuit meets the dimensional and performance requirements of specification MIL-C-8379.

• **Johns-Manville Sales Corporation . . .** An illustrated 12-page brochure that contains 101 suggestions for maintaining plant buildings and equipment has been issued. It includes information on insulations, packings, refractory products, friction materials, and roofings. This booklet, "Good Operating Practices," is available from the J-M office at 22 E. 40th St., New York 16.

• **Lear Incorporated . . .** A new seat actuator, Series 2450, has been introduced by the company to meet aircraft requirements for a seat adjustment actuator capable of withstanding the high loads incurred by latest explosive seat ejection equipment. Lear states that maximum operating loads are 700 lbs. tension or compression and that maximum static loads of 6,600 lbs. tension can be withstood without permanent deformation. Ultimate static strength of the new linear actuator as a heavy-duty structural member is approximately 11,000 lbs. Exact ultimate static strength, the company reports, varies somewhat with the length of the jackscrew at the time of explosion. This 8.3-lb. electromechanical seat actuator has an operating temperature range of −65° to +170°F. Further information may be obtained by contacting Lear's Department 80 at 110 Ionia, N.W., Grand Rapids 2, Mich. . . . A new product known as ARCON has been announced. According to the company, ARCON is a 12-lb. single-purpose instrument designed to keep the airplane in straight-line flight and to prevent its entering an unintentional spiral. ARCON consists of three major components: an electric motor-driven servo-actuator assembly, an amplifier, and a rate gyro.

• **Lockheed Aircraft Corporation . . .** The Lockheed F-80 Shooting Star that became this country's first operation jet fighter to set a world speed record has been placed on permanent display in the Air Force Technical Museum at Dayton, Ohio. This particular flight was made on June 19, 1947, at a speed of 623.8 m.p.h. The pilot on this occasion was Major Gen. Albert Boyd, now Commanding General of Wright Air Development Center; General Boyd then held the rank of Colonel and was Chief of Flight Testing at Wright-Patterson AFB, Ohio.

• **Marquardt Aircraft Company . . .** Robert L. Earle has been elected Executive Vice-President of Marquardt. Mr. Earle joined the company last September 1 as Vice-President—Administration and Assistant to the President.

• **The Glenn L. Martin Company . . .** A 34-page brochure that details the development and applications of "Marbond" is available to engineers and industry executives. "Marbond" is a "trade name embracing Martin honeycomb core, Martin sandwich material, Martin adhesive and the entire process of structural bonding invented and perfected by The Glenn L. Martin Company."

• **Minneapolis-Honeywell Regulator Company . . .** The Aeronautical Division has announced a new electronic fuel measurement system for aircraft in which a single amplifier power unit serves several indicators by receiving and sorting signals from two different fuel tanks simultaneously. The new system, known as the Multiplex Fuel Gauge, eliminates one power amplifier for every two indicators. For a three-unit installation using a separate tank sensing element, power amplifier, and cockpit indicator, the power unit can be provided with either vacuum tubes or transistors. A two-unit system is also available in which the transistorized power unit and cockpit indicator are combined. This system is suitable for either separate indication of two different tanks or simultaneous indication in two locations of the readings from a single tank. . . . An electronic testing system that permits engineers to estimate the effect of the addition

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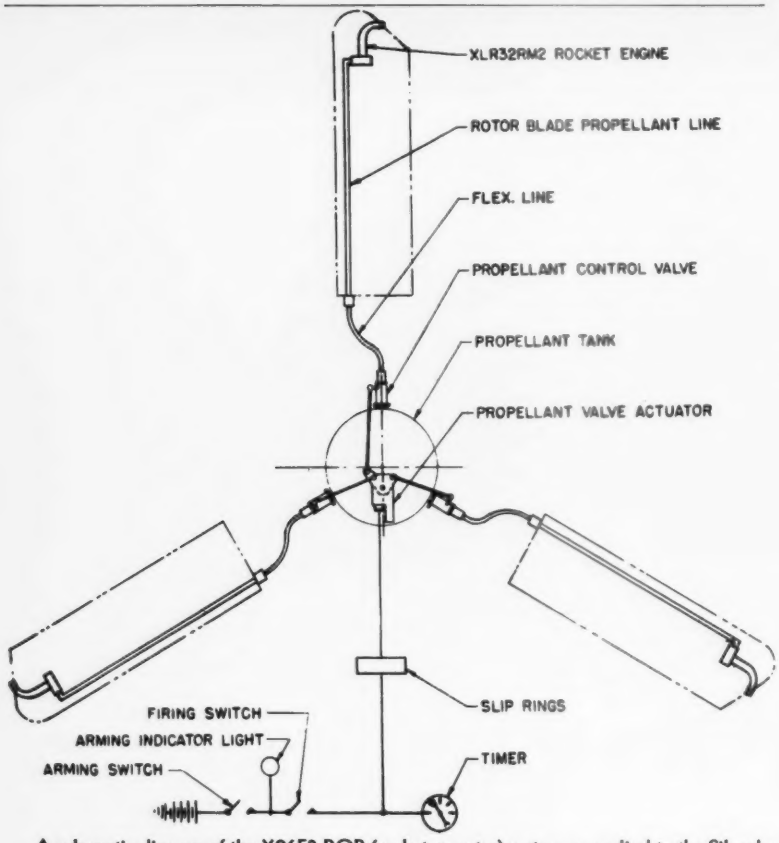



**A schematic diagram of the X96F3 ROR (rocket on rotor) system as applied to the Sikorsky HRS-2 helicopter. The ROR system was designed and developed for the U.S. Navy by Reaction Motors, Inc. See Reaction Motors news item on this page.**

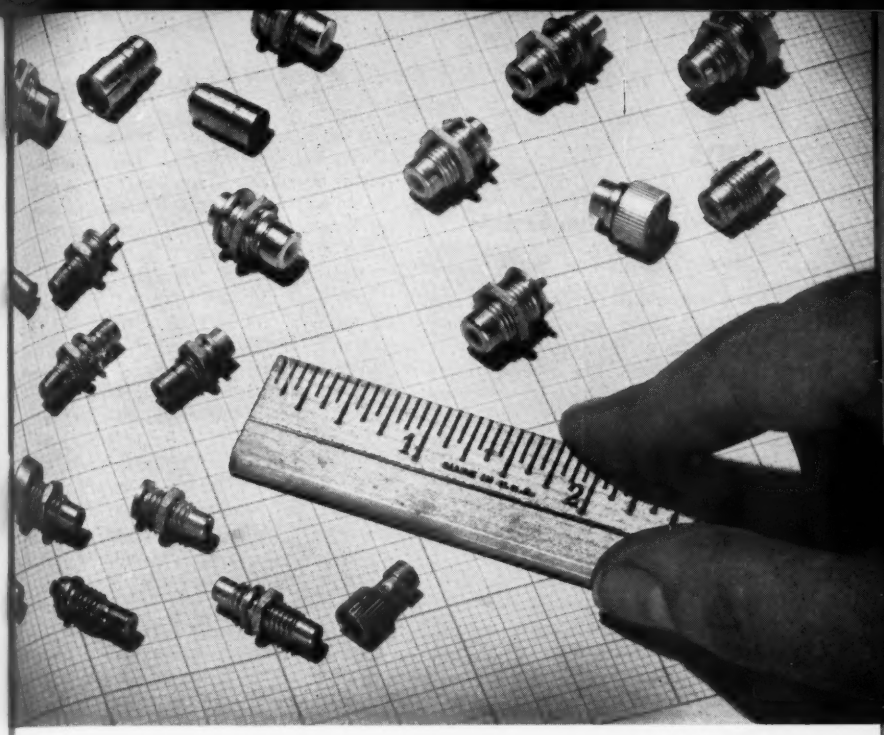
of new equipment to an industrial operation without actually test-installing such equipment has been announced by the company. Known as a servo analyzer, this new system was developed by the Industrial Division and is said to translate behavior characteristics of equipment to a chart record automatically. The servo analyzer is said to have many applications, among them being in the development of jet-engine components. . . . John W. Morrison has been named Comptroller of the Aeronautical Division.

• **North American Aviation, Inc. . . .** The U.S. Air Force has ordered an undisclosed number of the F-86K, the sixth model of the Sabre series. The "K's" are to be built at North American's Los Angeles plant. The new fighter is almost identical in appearance to the rocket-firing F-86D, except for an additional 8 in. to the fuselage length. The chief difference is armament, which consists of four 20-mm. cannon instead of the 24 "Might Mouse" rockets carried by the "D." . . . Tooling for F-100 Super Sabre production has been started at the Columbus, Ohio, plant, and deliveries are expected to begin about late summer or early fall of 1955. The F-100 has been in production at the company's main plant in Los Angeles since mid-1953 and will continue to come off the assembly lines of this West Coast plant. . . . Two new electronic devices—an Angle of Attack Calibrator and a Vane Jump Angle Computor—have been developed to provide more accurate fire control systems of rocket- and missile-armed military aircraft. The Calibrator measures the airplane's angle of attack in trimmed unaccelerated flight at various combinations of Mach Number, altitude, and fuel weight. The Computor, called NAVJAC, computes the relative jump angles of rockets fired during straight-line trimmed-flight conditions of aircraft traveling at high speed. The NAVJAC consists of five elements: a computor, a shock mount, two electromagnetic pickoffs, two vanes mounted on either side of the fuselage, and a Mach pickoff. The unit weighs $10^1/_4$ lbs. . . . A 20-lb. VHF two-way communications unit that occupies less than 1 cu.ft. of space has been announced by the company for use in military and commercial aircraft. This eight-channel crystal-control transmitting and receiving device is available for either code or voice communications.

• **Reaction Motors, Inc. . . .** A liquid-propellant rocket-engine system that gives a helicopter extra power to lift heavy loads or to fly from high-altitude fields was given its first public demonstration last September on a Marine Corps HRS-2 helicopter. Designed and developed for the U.S. Navy by Reaction in cooperation with United Aircraft Corporation's Sikorsky Aircraft Division, manufacturers of the HRS-2, this system includes: (1) three small tip-mounted rocket engines, each weighing about 1 lb.; (2) a propellant tank mounted above the rotor hub and holding sufficient hydrogen peroxide fuel for 6 min. of operation or 20 to 25 take-offs; (3) propellant lines; and (4) a few valves and controls. (A schematic diagram of this system appears on this page.) The dry weight of the whole system for the three-bladed HRS-2 helicopter installation is approximately 67 lbs. Known as ROR (rocket on rotor), it reportedly permits a helicopter to take off at sea level with appreciably greater loads, provides considerably improved glide performance and control in the event of main-engine failure, and greatly improves the rate of climb and hovering ceiling at any fixed gross weight. The ROR system can be adapted to any existing HRS-2 helicopter as well as to other types.

• **United Air Lines, Inc., and Standard Oil Company of California . . .** A contract, recently executed by United and Standard Oil of California, covers the purchase from the latter company of over $50,000,000 worth of gasoline and allied petroleum products. The contract is designed to take care of the petroleum needs of the western section of United's system for the next 4-year period.

• **Vickers, Inc. . . .** A new line of variable-displacement piston-type aircraft hydraulic pumps which achieves up to 37 per cent savings in weight and as much as 33 per cent reduction in size is now available from Vickers. A special magnesium-zirconium alloy used for the pump housing contributed to the savings in weight, while a redesigned cast alloy steel yoke made possible the size reduction. The company reported that the new pump has demonstrated under test conditions its ability to retain the same high volumetric efficiency (more than 96 per cent) and high overall efficiency (more than 92 per cent) of predecessor designs. The new pumps, which passed the 560-hour military test last July, are said to operate with substantially lower critical inlet pressures than former designs. The new pump series is designed for 3,000-lb. per sq.in. operation and is available in sizes having nominal rated deliveries (at 1,500 r.p.m.) from 0.60 to 23 g.p.m. The smaller size pumps can operate at speeds as high as 9,100 r.p.m. Operating temperature range is $-65°$ to $+160°$F. Specially equipped pumps permit operational temperatures beyond these limits. The pumps can be of either uniflow or over-center design. Cylinder controls can be provided to maintain a selected pressure automatically while delivering a varying flow depending upon system requirements. An electric depressurizing control can be provided which will cause the pump to lock at minimum pressure and zero displacement while remaining instantly prepared to meet system requirements upon demand. Servo control arrangements are available which permit remote control of hydraulic power in response to an electronic signal of a few milliamps. A simple control piston can be provided for the variable displacement pump which will respond to hydraulic control pressures originating in a device supplied by the customer apart from the Vickers hydraulic components.



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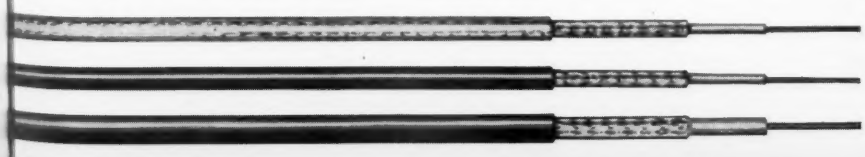
## AMPHENOL SUBMINAX RF CONNECTORS

A complete line of 50 and 75 ohm RF connectors, so small that all of the twenty-two connectors in the series easily fit in the palm of your hand!—the ruler certainly tells the story of the amazing new AMPHENOL ***subminax*** RF connectors! A result of the continuing AMPHENOL development work in the field of miniaturization, the new ***subminax*** connectors have all the dependable features of their older, larger brothers compressed into a fraction of the space usually demanded in RF connectors!

The ***subminax*** line is exceptionally complete. Connectors are available in both screw-on and push-on types in either 50 or 75 ohms. In each design there is a plug, jack, receptacle, jack bulkhead and feed through. In addition, *hermetically sealed* receptacles are available in the 50 ohm and 75 ohm screw-on connectors. Construction? ***Subminax*** connectors have machined brass bodies with a tough and shining gold-plated finish.

Although ***subminax*** cable assemblies are available directly from AMPHENOL, assembly at your plant is both easy and practical. Inexpensive and easy-to-use *hand crimpers* are available along with the necessary lengths of AMPHENOL Miniature Coaxial Cable.



50 ohm Push-on

| Part No. | Description |
|---|---|
| 27-1 | Plug |
| 27-2 | Jack |
| 27-3 | Receptacle |
| 27-4 | Jack Bulkhead |
| 27-5 | Feed Through |

50 ohm Screw-on

| Part No. | Description |
|---|---|
| 27-5 | Plug |
| 27-8 | Jack |
| 27-9 | Receptacle |
| 27-10 | Jack Bulkhead |
| 27-11 | Feed Through |
| 27-12 | Receptacle, Hermetically Sealed |

75 ohm Push-on

| Part No. | Description |
|---|---|
| 27-13 | Plug |
| 27-14 | Jack |
| 27-15 | Receptacle |
| 27-16 | Jack Bulkhead |
| 27-17 | Feed Through |

75 ohm Screw-on

| Part No. | Description |
|---|---|
| 27-19 | Plug |
| 27-20 | Jack |
| 27-21 | Receptacle |
| 27-22 | Jack Bulkhead |
| 27-23 | Feed Through |
| 27-24 | Receptacle, Hermetically Sealed |

MINIATURE COAXIAL CABLE

Three types of miniature coaxial cable are available from AMPHENOL for making *subminax* assemblies. These are 50 ohm and 75 ohm polyethylene dielectric with black vinyl jacket cable and a 50 ohm Kel-F dielectric and Kel-F jacket cable.

| Part No. | RG-/U No. | Impedance | Description |
|---|---|---|---|
| 21-596 | — | 50 ohm | Kel-F |
| 21-597 | — | 75 ohm | Poly. |
| 21-598 | 174 | 50 ohm | Poly. |

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# IAS Sections

## Chicago Section

Leland W. Sims, *Secretary*

The first meeting of the Chicago Section's 1954–1955 year drew a large and interested group to the Glenview Naval Air Station on October 6.

At 6:00 p.m., the group was given a flight demonstration of the Navy's Piasecki HUP-2 helicopter in front of the administration building of the Air Station. The air-sea rescue helicopter was piloted by Commander Norris, who put the craft through intricate maneuvers demonstrating the versatility and adaptability of the helicopter to rescue missions.

The group was then taken by bus to the Officers Club for a cocktail hour, sponsored by Piasecki Helicopter Corporation. At 8:00 p.m. dinner was served in the main dining room of the club to 140 members and guests.

At 9:00 p.m., the meeting was opened by Richard A. Schram, Section Chairman. Mr. Schram introduced the members and guests at the speakers table and the speaker of the evening, Harry S. Pack, Vice-President of Piasecki Helicopter Corporation. Mr. Pack presented a paper that was to have been delivered by Frank N. Piasecki, who was unable to attend. The title of the paper was "The Helicopter, A New Factor in Containerized Transportation."

Mr. Pack emphasized the importance of speeded-up logistics operations in connection with any possible future conflict. He illustrated with examples drawn from both the Revolution and World War II that in a period of 176 years the speed of flow of military supplies had been increased by only 2 m.p.h. He pointed out several causes of the present low rate, particularly those of packaging and handling. The helicopter of large transport type with a detachable pack or pod might serve as the missing link between the initial carrier and the field forces. He emphasized also the necessity of a standardized pre-loaded all-weather container adaptable to all types of conveyances.

Mr. Pack cited the accomplishments to date in this direction and showed with slides the designs that have been flight tested successfully. Mr. Pack also explained the economic factors in favor of container-type craft as compared to internally loaded aircraft.

A motion picture was also shown which illustrated the development of several models of Piasecki helicopters.

Following a discussion period, Mr. Schram concluded the program at 10:45 p.m.

## Cleveland-Akron Section

Howard F. Powders, *Secretary*

The Cleveland-Akron Section held its first meeting of the 1954–1955 season on September 28 at the Hotel Mangor in Cleveland. Before the evening meeting, a tour for members was conducted through the plant of the Cleveland Pneumatic Tool Company, the organization that also sponsored the social hour.

The main speaker was Maynard L. Pennell, Chief Project Engineer of Boeing Airplane Company. His topic was "The Evolution and Design of the Boeing Jet Tanker Transport Model 707." In his talk, Mr. Pennell compared the performance characteristics of the 707 with those of propeller-driven aircraft and listed the advantages of the two types. His lecture was illustrated with slides and a color motion picture.

## Dayton Section

G. R. Graetzer, *Secretary*

On September 23, the Dayton Section started its first meeting of the 1954–1955 season at 6:30 p.m. at the Civilian Club, Wright-Patterson AFB, Ohio. After an enjoyable social hour and dinner, attended by 61 members and guests, last year's Chairman, Charles L. Hall, introduced the new Chairman, George J. McTigue. He installed the new officers—W. D. Dodd, Jr., as Vice-Chairman, G. R. Graetzer as Secretary, and T. J. Keating as Treasurer—and the new Council. He expressed his regrets that the Honorary Chairman, Rear Adm. T. C. Lonnquest, could not be present. The Section felt honored in having E. S. Thompson, IAS Vice-President, as a guest at the meeting. The Chairman announced that the forthcoming meetings would feature discussions on "Supersonic Accessories" and the "Aerobee Sounding Rocket" and a tour of Aeroproducts Operations at Vandalia, Ohio.

After the completion of clearance procedures, the group was taken by Air Force buses to the Air Force Technical Museum of the Wright Air Development Center. This museum, under the direction of L. B. Jarnagin, is the successor to an Army Aeronautical Museum, established in 1923 and since destroyed by fire. A new building, constructed with Public Works Administration funds, was first opened to the public in 1936, but was closed during World War II for security reasons. The museum, transferred to a larger building, now contains about 20,000 major end items of outstanding historical significance and usefulness for active research projects. The astonishing achievements of the Wright brothers cover only a small part of the exhibition of letters, pictures, and models which were of great interest.

New groups of persons continually gather around the original contract of the Wrights in 1908 with the U.S. Army. In this contract, the Army agreed to purchase a plane from the Wrights with the following provisos: if the plane flew at 40 m.p.h., 100 per cent of the specified price would be paid; however, for each mile under 40 down to and including 36 m.p.h., the specified purchase price would drop 10 per cent. Thus at 36 m.p.h., 60 per cent of the purchase price would be paid. If the plane flew less than 35 m.p.h., the Army would reject it. The contract goes on to state that 10 per cent would be added to the specified price for each mile that the plane could fly over 40 m.p.h. When the plane was finally built and flown, it went at 42 m.p.h., and, under the terms of the 1908 contract, the Army paid the specified price of $25,000 plus 10 per cent for each additional mile or 20 per cent. This brought the total paid to the Wrights to $30,000. An additional stipulation in the contract was that the plane could be packed for transportation on Army vehicles and could be assembled within 1 hour.

Other objects of special interest were portraits of famous airmen, flags, "blunder" trophies, propellers, parachutes, a B-61 Matador missile and launcher, the deceleration vehicle used at Edwards AFB by the Aero Medical Laboratory, a prototype X-3 and B-57 Canberra, an XB-36 landing wheel, a stratosphere gondola, some full-scale modern aircraft, and over 5,000 items of foreign equipment.

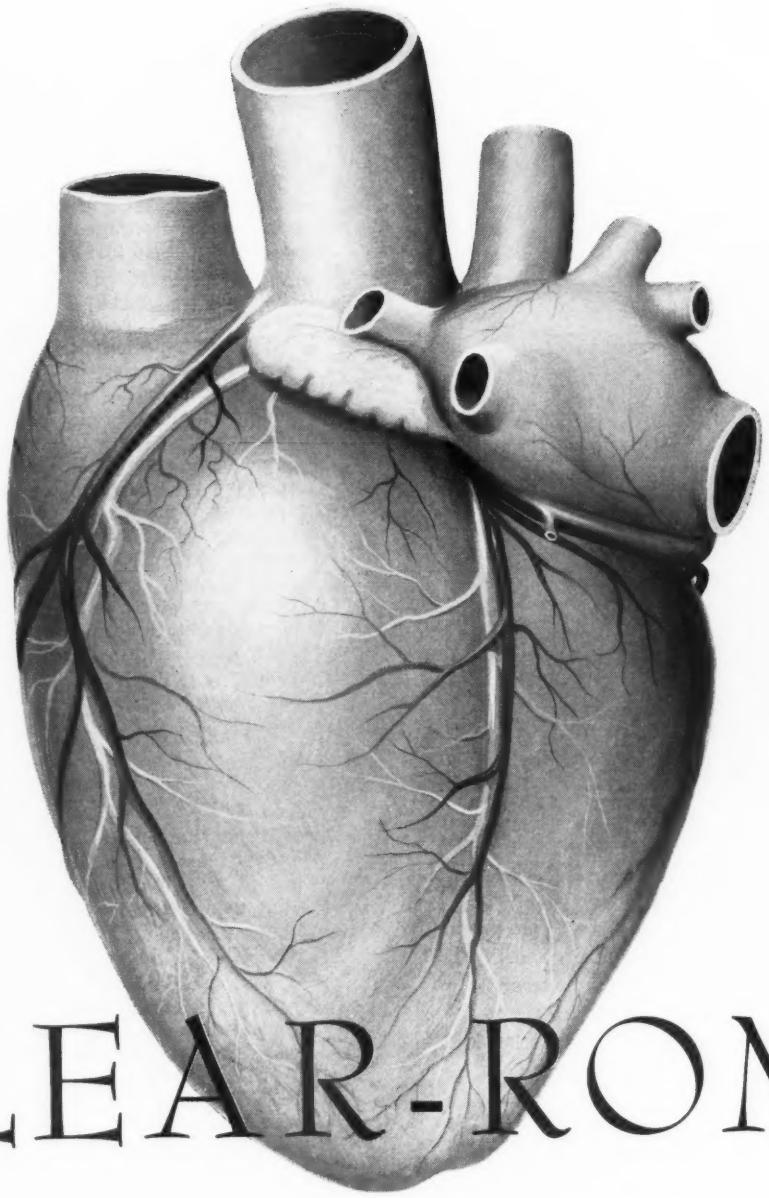
The museum is charged with collecting, cataloging, filing, and servicing technical and historical data relative to the development, operation, and maintenance of aeronautical equipment. The museum library maintains a collection of all Technical Orders and Supply Catalogs from 1926 through the present time as well as the "Standard Documents" dating back to the beginning of Air Force history. The museum has its own workshops in which artists, designers, wood workers, and model makers are building museum displays for specific exhibits.

The tour, lasting 1½ hours, gave an unusually complete picture of the history of flight.

## Hagerstown Section

George W. Westphal
*Outgoing Secretary*

The initial meeting of the fall season was a dinner meeting held at the Foun-



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tain Head Country Club on September 22. Forty-four members and guests were present.

The officers installed for the coming year are: Chairman, T. H. Beck; Vice-Chairman, R. E. Eisiminger, Jr.; and Secretary-Treasurer, E. A. Stannard. The Advisory Council is made up of J. A. Neilson, L. Fahnestock, III; and E. R. Gelvin. The Representative to the Area Nominating Committee is M. C. Marlow.

The meeting was opened by the outgoing Chairman, R. A. Darby, who expressed his appreciation to the members who had assisted him during this term of office.

The meeting was then turned over to the incoming Chairman who briefly mentioned some of his thoughts concerning the coming year's activities. Mr. Beck informed the group that, because of personal reasons, Mr. Stannard was unable to continue as the elected Secretary-Treasurer. The matter was referred to Nominating Committee Chairman Weller for further action.

George White introduced the guest speaker, Robert Sanders, of Sanders Aviation, who discussed some of the trends and various aspects of private aircraft and their operation.

The meeting was adjourned at 10:00 p.m.

## Hampton Roads Section

William D. McCauley
*Recording Secretary*

The first meeting of the year was held on September 15 at the Activities Building of the NACA, Langley Field. More than 70 IAS members and guests were present along with a representation of the local Icarian Flying Club.

The speaker for the evening, William T. Piper, Sr., was introduced by Emanuel Boxer, the new Section Chairman. Mr. Piper had flown down with his son in a new twin-engined Apache, which they had demonstrated during the afternoon to interested members. An early leader in the light plane industry, Mr. Piper was associated with C. G. Taylor as a Director of the Taylor Aircraft Corporation from 1929 to 1936.

Mr. Piper's talk was entitled "A Discussion of Private Flying." He stated that in the early days of the depression he realized that a small low-priced easy-to-fly airplane was needed. When he first began to manufacture this type of aircraft, production was on an average of 70 planes in 3 years. In time, this was increased to 70 in a single year and later to 220 per year. During the war, his company produced over 5,000 trainer and liaison aircraft.

Mr. Piper said that Piper Aircraft Corporation noted that the private pilot wanted a cheap side-by-side air-

plane. In answer to this need, the Piper organization designed the Vagabond by cutting 6 ft. off the J-3 trainer's wings and changing the fuselage. When a trend towards a four-place aircraft became apparent, Piper again redesigned the fuselage and increased the horsepower; this airplane was named the Clipper. Because of legal difficulty, the name was changed to Pacer. The Tri-Pacer with its tricycle landing gear followed the Pacer.

After discussing this general background, Mr. Piper turned to the problems facing the light-plane builders. Today, he said, the industry is catering to the people who travel, the tendency being toward larger planes and very little toward sport flying. The two-place aircraft, Mr. Piper feels, has now become a special-purpose type, and the low-priced airplane will probably be a good third- or fourth-hand airplane. Today, Piper Aircraft Corporation is concentrating on the twin-engined Apache, producing it as an economical all-purpose executive-type aircraft.

At the conclusion of the discussion, the members and guests stayed for refreshments and an opportunity to visit with one another.

## Los Angeles Section

Joseph W. Wechsler
*Section Secretary*

On September 16 at the first dinner meeting of the Los Angeles Section this fall, Lt. Comdr. James L. Holbrook, USN, spoke on "Progress in Carrier Operations."

The major advance in launching aircraft has been the steam catapult. This basically simple mechanism uses steam from the ship's main boiler system in place of hydraulic fluid activated by a separate power plant. Its potential capacity is estimated to be several times that of hydraulic catapults with only a slight weight increase. It can therefore launch much larger aircraft and usually without regard to the direction of the wind across the deck. This results in significant tactical and logistic advantages.

The major advance in landing techniques has been the angled or canted deck. Since a bad landing on a canted deck does not threaten the pilot with a crash into parked aircraft and personnel elsewhere on the deck, the pilots using the canted deck have become more relaxed and confident and are making better landings than ever before. Other advantages are shorter intervals between landings, reduced number of arresting wires necessary, and elimination of the need for flush decks.

The talk was illustrated by a movie of steam-catapult launchings from the deck of the U.S.S. "Hancock" and by slides


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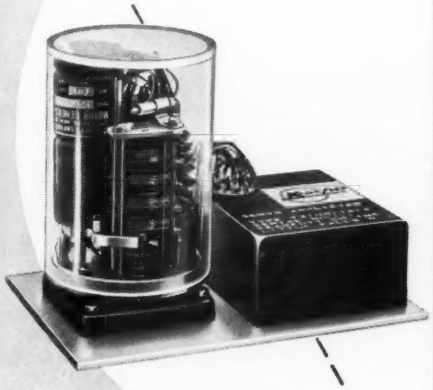

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ADAC is a device for the precise electro-mechanical conversion of analog information to digital form. ADAC works from a synchro voltage input and produces a 12-binary-digit informational output.

This servo driven Converter is designed to be read-out either "on the run" or "on demand". For read-out, the digital computer sends an interrogating pulse to all the drums (and their segments) in common. The pulse can only return to the computer via the brushes contacting the tracks. If a brush is on a conducting segment, the pulse returns to the computer; if the brush is on an insulated segment, the pulse is blocked. All 12 tracks are simultaneously read and the return pulses are thus coded to represent discrete steps of the transducer feeding ADAC.

By using precision servo components, the accuracy of ADAC has been reduced to one part in 4096 (.02%), or approximately 5 minutes of transmitter rotation. It weighs only 2½ pounds and measures three inches in diameter and four inches in length. The device is hermetically sealed and is highly shock resistant. The T3100 Servo Amplifier provides the necessary excitation for the servo elements of the Converter. A direct drive ADAC providing the segmented drums and necessary gear trains, and an inverse ADAC for digital-analog conversion is available.

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showing the deck arrangements of carriers being built or modified to canted-deck configurations. Also mentioned were some further improvements in carrier operations which are being explored, such as straight-in approach and completely automatic landing.

In summary, Commander Holbrook pointed out that the limiting factor in the advancement of carrier operations probably will be the maximum accelerations and decelerations to which the pilots can be subjected and still be able to control their aircraft through the launching and landing operations.

Presiding at the meeting was R. Richard Heppe, Section Chairman for the year just completed. The Section's annual business meeting was conducted before the main address of the evening, and the officers for the coming year were installed.

### San Diego Section

H. C. Matteson
*Corresponding Secretary*

The San Diego Section held its annual business meeting on September 28 at the San Diego Institute of Aeronautical Sciences building. The evening's activities included a social hour, dinner, and meeting at which the officers for the coming year were installed. A talk on the Ryan Firebee target drone was presented.

Retiring Section Chairman Herman Braasch presided over the meeting. He summarized the year's activities, which included five dinner meetings, two nondinner meetings, nine technical meetings, a field trip, two dances, and a family night. Chairman Braasch noted with pleasure that the Section membership exhibited a healthy growth throughout the year and now stands at 264 (including 10 applicants). Membership Committee Chairman Don Germeraad was most instrumental in achieving this growth.

Past Chairman Dwight Bennett presented retiring Chairman Braasch with the past Chairman's key. This is a traditional event at San Diego, the key being a symbol of appreciation from the membership for the retiring Chairman's efforts on behalf of the Section.

The incoming Section officers were installed by past Chairman Bennett. They are: Chairman, James G. Wenzel, Flight Test Engineer, Convair; Vice-Chairman, Earl R. Hinz, Aerodynamics Engineer, Ryan; Treasurer, Harry C. Matteson, Aerodynamics Engineer, Convair; Corresponding Secretary, James M. Adamson, Structures Engineer, Convair; and Recording Secretary, Donald P. Germeraad, Project Test Pilot, Convair.

Bruce Smith, Director of Engineering, Ryan Aeronautical Company, discussed the design and development of the Ryan Firebee target drone, which is being constructed for all three branches of the armed services. Mr. Smith augmented his talk with a full-scale Firebee display and a movie covering flight-test procedures. The Firebee is a small swept-wing jet-propelled radio-controlled aircraft capable of speeds up to 0.9 Mach Number and altitudes up to 40,000 ft. It may be launched from a parent aircraft or boosted from a ground launcher. It features a parachute recovery system that eliminates the complication of a retractable landing gear and yet assures a safe recovery, thereby permitting the drone to be used repeatedly.

During the design of the Firebee, emphasis was placed on simplicity in order to have a reliable piece of equipment which would be comparatively easy to operate. Flight testing revealed high-speed aerodynamic problems similar to those encountered on fighter aircraft. Mr. Smith's talk was an interesting and informative presentation of a new type of aircraft designed to fulfill a new requirement.

An audience of approximately 100 members and guests fully enjoyed this sociable and educational evening.

## Student Branches

### Indiana Technical College

Bernard E. Heyl, *Secretary*

The IAS Student Branch of Indiana Technical College met on September 28, with Chairman John B. Wright presiding. There were 57 people in attendance.

Discussion was held on a proposed field trip to the NACA laboratories in Cleveland. A motion to make the trip on October 29 was carried.

A committee was selected to initiate action on an airplane that is to be designed and built by the Tech students. A contest will be held to determine which sport-plane design is most acceptable.

R. E. Robertson, of the CAA Control Tower at Baer Field, was introduced by the Honorary Chairman, Ben L. Dow.

Boeing's release entitled *Wind Tunnel Testing of Elastically Scaled Models of the B-52 and B-47* was shown; and Ben Kemp, Instructor in charge of Wind Tunnel Testing at Tech, explained the significance of the picture.

### Iowa State College

John Midgorden, *Secretary*

Student Branch Members were brought up to date on general developments in the aircraft industry by Prof. M. L. Millett's talk on September 29. Professor Millett described the airplanes now being developed by the major aircraft producers and new developments in the air-line field.

Three Student Members, Walter Dunn, John Midgorden, and Walter Livezy, gave short talks on their experiences as summer employees in the aircraft industry.

The current Student Officers are: Chairman, Phillip Smith; Treasurer, Dennis Holstein; and Secretary, John Midgorden.

Charles Paton has been elected Publicity Chairman to represent our Student Branch at the forthcoming Engineer's Carnival, a special local event. Carl Anderson and Jim Brommer have been elected Co-Chairmen in charge of the IAS Student Branch booth at this campus function.

### Oklahoma Agricultural and Mechanical College

Kendrick Coryell
*Secretary-Treasurer*

The Oklahoma A&M Student Branch of the Institute of the Aeronautical Sciences held its first meeting of this school year on September 23. There were 15 present. This was a general business meeting. A Faculty Adviser was selected, organizational committees were appointed, and plans for the coming year's activities were discussed. Professor Ladislaus J. Fila was elected Adviser.

▶ The Oklahoma A&M student branches of the Society of Automotive Engineers, American Society of Mechanical Engineers, American Institute of Mining Engineers, and the Institute of the Aeronautical Sciences have set up a series of joint meetings to be held once a month. The responsibility for the programs will be rotated among the participating organizations. The object of this is to attract attendance large enough to merit good speakers from industry. These joint meetings are held in addition to the regular monthly meetings of each group.

The first joint meeting was held September 28 with attendance of 150. The speaker was Vincent Kaptur, of the Styling Section of General Motors Corporation, who spoke on "Styling and the Engineer." He discussed the necessity for the Styling Section—an integral part of the automobile industry. Each Design Department of General Motors (one for each make of car produced) is separate; each is in competition with the others. He defined the difference

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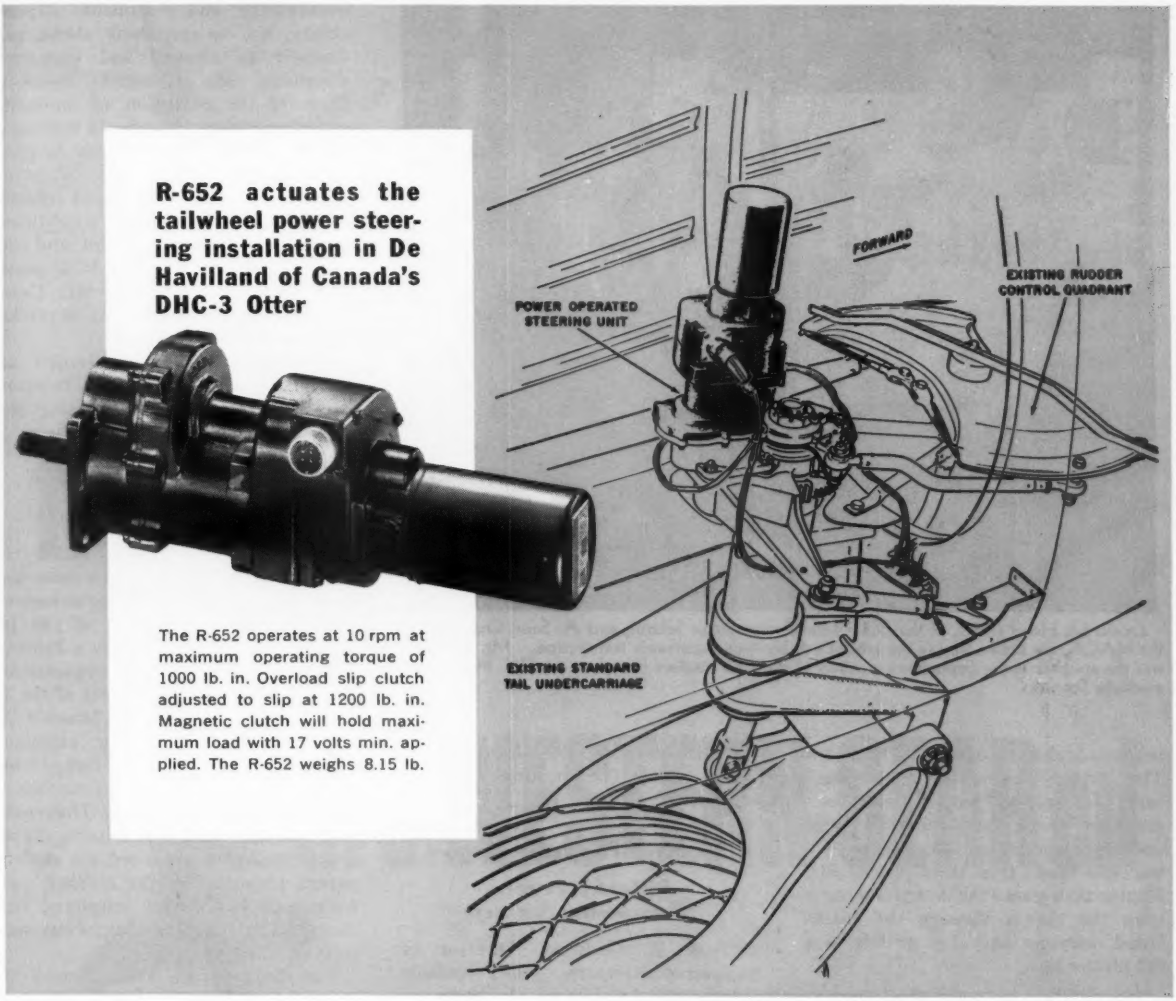


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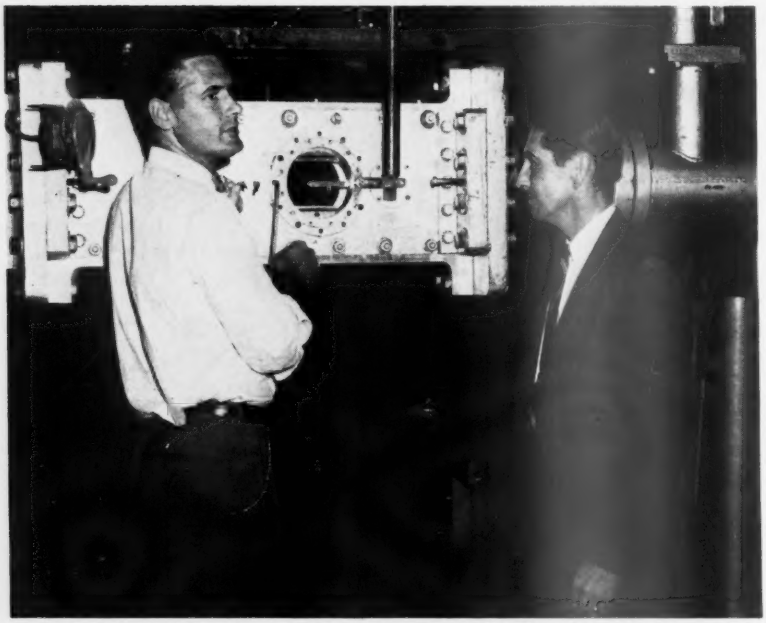


**Dr. R. M. Head *(left)*, of the U.S. Naval Postgraduate School, and A. Scott Crossfield, of the NACA, are shown beside the school's 4- by 4-in. supersonic test section. Mr. Crossfield was the speaker at the September meeting of the IAS Student Branch at the U.S. Naval Postgraduate School.**

between Stylist, Designer, and Engineer. The Stylist draws the "futuristic" cars; the Designer "tames" the Stylist's drawings down to practical plans; and the Engineer actually develops a workable model from these plans. Mr. Kaptur then traced the design of a car—from the sketch through the blackboard drawings and clay models to a full plaster cast.

Present plans are for the IAS Student Branch to provide the program for the December joint meeting.

## The Pennsylvania State University

E. Allen Weber, *Secretary*

The first scheduled meeting of The Pennsylvania State University Student Branch of the IAS was held on September 28 on the Penn State campus with 60 aeronautical engineering students present. Chairman Ralph Straley presided.

After a welcome was extended to the students at their first meeting, the incoming officers were introduced. Each of the officers briefly outlined his specific duties.

Chairman Straley mentioned some of the advantages of joining the IAS. Our Faculty Adviser, John A. Fox, then made a few statements concerning the organization and functions of the IAS. Following a discussion of awards for scholarship and technical papers, the award for the best technical paper written last year was presented to Emil M. Kaege.

A British film, *The Airscrew*, was shown next. The meeting was then adjourned.

## U.S. Naval Postgraduate School

Richard J. Peterson
*Corresponding Secretary*

Frank E. Goddard, Director of Supersonic Research, Jet Propulsion Laboratories, California Institute of Technology, was the speaker at our meeting on August 18. Mr. Goddard's topic was the development and operation of the supersonic and hypersonic wind tunnels at the Jet Propulsion Laboratories.

At this August meeting, the following officers were elected: Chairman, Lt. Francis J. Readdy, USN; Vice-Chairman, Lt. Marland W. Townsend, USN; Secretary-Treasurer, Lt. Joseph N. Kanevsky, USN. Dr. R. M. Head, Professor of Aeronautics, continues his Honorary Chairmanship of the Branch.

▶ In September, our second meeting, A. Scott Crossfield, Aeronautical Research Assistant, NACA High-Speed Flight Station, Edwards AFB, Calif., spoke on "The Flight Testing of Supersonic Aircraft." The film *High-Speed Flight* was shown.

Mr. Crossfield outlined the development and the purposes of the various "X" series and the D-558 transonic and supersonic research aircraft. He expressed the view that the human pilot is far from being replaced by servomechanisms and "black boxes" in aircraft. Not only has the human pilot nonlinearity and reasonable dependability, but he can think ahead, particularly in unusual and emergency situations. Mr. Crossfield spoke in favor of the reduction of automatic gadgetry and some duplicate systems in aircraft so that the pilot may be given greater responsibility.

This talk by Mr. Crossfield reflected his wide experience as a wind-tunnel aerodynamicist, military pilot, and pilot and engineer with the NACA supersonic research program. Mr. Crossfield has flown the Douglas Skyrocket at a speed of Mach 2.01.

A business meeting preceded adjournment. Lt. Richard J. Peterson, USN, was elected Corresponding Secretary for our Student Branch.

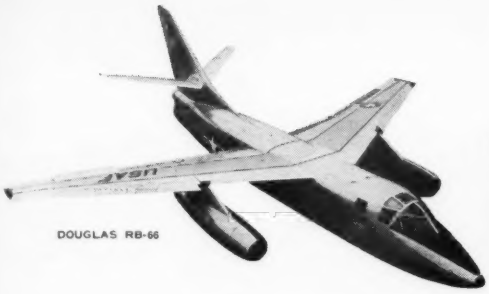
## University of Michigan

Roger J. Nyenhuis, *Secretary*

Chairman Bill Sproull called the meeting of September 29 to order and gave a preview of the coming semester's activities. The objectives of the Institute and our relation, as a Student Branch, to the senior organization were explained for the benefit of the 32 new members. Professor Maurice A. Brull, our Faculty Adviser, explained the annual student paper competition in which the IAS Student Branches at Wayne University and the University of Detroit also participate. Professor Brull then discussed the student papers presented at the regional conferences in order that interested students might begin thinking about subjects on which to write.

For the program, Prof. Arnold M. Kuethe described the Traveling Seminar on aeronautical developments with which he and Prof. Julius D. Schetzer had been occupied throughout the summer. This Traveling Seminar took them through most of the countries of Europe, which, Dr. Kuethe said, were somewhat behind the U.S.A. in aeronautical developments because of the accelerated research and development program conducted in this country during and since World War II.

Several members described the engineering jobs they had held during the summer. Ralstom Schultz had been at Douglas Aircraft Company, Inc.; Galen Podesta, at Lockheed Aircraft Corporation; Joseph Morelewski, at Bell Aircraft Corporation; and Bill Sproull, at Boeing Airplane Company. These men explained the work they did and how they had been treated by these various companies. Questions were asked from the floor concerning the companies being discussed. It was concluded that more experience could be obtained from a company having a program for students working in engineering for the summer than from a company not having a planned program.



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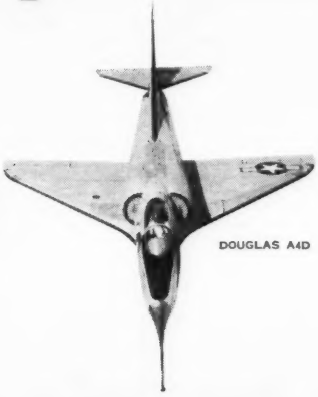

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**WORLD'S FASTEST PROPELLER-DRIVEN AIRPLANE** is turbo-propeller Super Constellation for the U.S. Navy (shown below). Now flying, it will be capable of speeds 100 mph faster than any propeller airplane now in service. Powered by Pratt & Whitney T-34 turbo-propeller engines, this plane promises new speed, new performance and greater economy potentials.

**NEWEST TRANSPORT CONCEPT** is Lockheed's C-130A turbo-prop assault transport, shown here in its dramatic first flight. Now in production at Government Aircraft Plant No. 6, operated by Lockheed's Georgia Division in Marietta, this giant plane literally jumped off the runway in one-third the distance required for today's commercial transports. This new cargo plane incorporates scores of new features for better handling of troops, materiel and equipment.

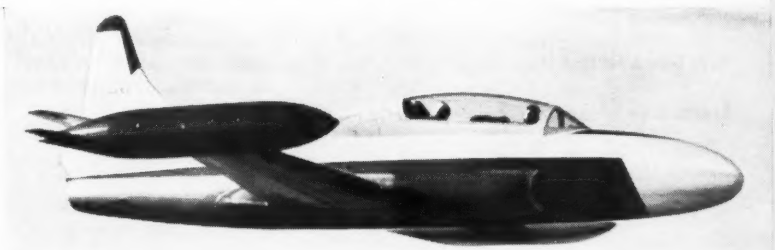
# 6 New Lockheeds for U.S. Protection

*Powerful Team Includes Truly Amazing Jet Fighter, High-Speed Assault Transport and Vital Picket Plane*

1954 has been a notable year for Lockheed, in research, development and production. Six new models in one year include: world's fastest propeller-driven transport; world's first turbo-prop assault transport; latest version of the Navy's Neptune anti-submarine patrol bomber; a new advanced jet trainer for the Navy, and a truly amazing jet fighter, the F-104 now in production, which is too secret to photograph or describe.

On these pages are shown all new models except the restricted F-104. Also photographed is the vital Super Constellation picket plane, with fantastic top and bottom radomes. The bottom radome, for example, creates between 30,000 and 60,000 pounds of drag pressure, yet to hold it securely in place only 10 bolts are needed, due to ingenious Lockheed design.

**FLIES STRAIGHT UP, LANDS STRAIGHT DOWN.** This is the Lockheed XFV-1 Vertical Ascender, a revolutionary new concept of aircraft developed in cooperation with the U.S. Navy. Now, every ship can have its own protective fighter umbrella, every back yard could become a landing field if needed.



**NEW NAVY ADVANCED JET TRAINER.** Often called the world's safest jet airplane, Lockheed's new T2V-1 advanced trainer for the U.S. Navy has so many new safety and performance features it can be used for carrier landing and takeoff and can utilize existing short fields for propeller aircraft. By training better jet pilots quicker, this trainer boosts Navy's ability to protect America. Another product of close Navy-Lockheed design teamwork.

**ADVANCED GUIDED MISSILE SYSTEMS DEVELOPMENT**

Eminent scientists, nuclear physicists, and engineers have joined forces at Lockheed's new Missile Systems Division in Van Nuys, California. Their mission is to solve the nation's prime defense problem, to give our armed forces *totally* reliable means of delivering our defensive and retaliatory weapons to their targets. To accomplish this vital task, Lockheed has appropriated $10,000,000 for a program of laboratory research and development.

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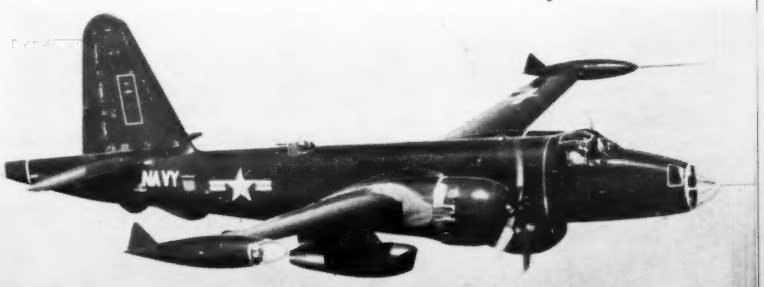
**NEWEST SUB HUNTER** is the Navy's latest version of the Lockheed P2V Neptune Patrol Bomber, a rugged, radar-laden flying sentinel with many secret missions. Its primary job: patrolling coastal waters against possible enemy submarines. Note new jet engines for added speed, power.



After the film *Air Age* had been shown, refreshments were served. The meeting was then closed.

### University of Tulsa

Wymon Barnes
*Secretary-Treasurer*

The first meeting of the 1954–1955 school year was called to order by the Student Chairman, Don Boyd, at 7:30 p.m. on September 23.

The office of Secretary-Treasurer was given to Wymon Barnes. The charge of maintaining an up-to-date Aero Science Club scrapbook was voluntarily accepted by Thomas Petri. It will be his responsibility to keep the Student Members informed on the latest developments in the aeronautical engineering field.

The Chairman gave a résumé of the functions of the Student Branch, outlining the advantages of Student Membership for the benefit of new members.

Two talks were delivered at this meeting. Don Funk, owner of D. D. Funk Aviation Company, Pryor, Okla., spoke on the design features of a crop-dusting airplane. He stressed pilot safety and explained the desirability of having the engine and the hopper in front of the pilot.

Dale Hannaford, who works in the Tooling Department at Douglas Aircraft Company, Inc., spoke on the aspects of tooling design as applied to the manufacture of aircraft. Mr. Hannaford described the various types of tooling design and current production methods.

At the adjournment of the meeting, a pre-arranged social hour followed in order that the total membership might become better acquainted.

# Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

### Elected to Associate Fellow Grade

**Binnie, Alan G.,** M.E., V-P & Asst. General Mgr., Kollsman Instrument Corp.

**Eckstein, Emil L.,** Sr. Design Engr. (Prelim. Design), Convair-Ft. Worth Div. of General Dynamics Corp.

**Greene, G. M.,** B.S., Research Physicist, Hughes Aircraft Co.

**Lindsey, Walter F.,** B.S. in E.E., Section Head, 24 High-Speed Tunnel Section, NACA, Langley AFB.

**Waite, Laurence L.,** B.S.Ae.E., V-P, Missiles & Control Equipment Div., North American Aviation, Inc. (Downey).

### Transferred to Associate Fellow Grade

**Hunter, Maxwell W.,** M.S., Asst. Supvr., Aerodynamics-Missiles, Douglas Aircraft Co., Inc. (Santa Monica).

**Laitone, Edmund V.,** M.S. in Applied Math., Prof. of Mech. Engrg., Univ. of California (Berkeley).

**Longfelder, Harlowe J.,** M.S.Ae.E., Staff Engr.—Aerodynamics, Boeing Airplane Co. (Seattle).

### Elected to MEMBER Grade

**Beckett, Walter R., Jr.,** B.S., Chief, Field Liaison Div., Hq. ARDC, USAF (Baltimore).

**Bennett, William C.,** B.S. in E.E., Production Liaison Engr.—Sr., Lockheed Aircraft Corp. (Marietta).

**Boring, R. F.,** B.S.M.E., Supvr., Installation & Service Engrg., General Electric Co. (Seattle).

**Clayman, Herbert S.,** B.S. in Civil Engrg., Tech. Asst. to Chief Proj. Engr.—Aircraft, Boeing Airplane Co. (Seattle).

**Farrow, John R.,** B.S.M.E., Sales Engr., East Coast District—AGTD, Westinghouse Electric Corp.

**Flath, Earl H., Jr.,** M.S. in Engrg., Lead System Design Engr., Chance Vought Aircraft, Inc.

**Gamsu, Sidney M.,** B. of Ae.E., Cons. Aero. Engr., Self-employed.

**Hopkins, John W.,** Sr. Design Engr., Convair-San Diego Div. of General Dynamics Corp.

**Horn, Herbert E.,** B.S.E., Process Engr. & Aircraft Devel. Engr., Grumman Aircraft Engineering Corp.

**Jackson, W. G., Jr.,** A.E., Capt. & Commanding Officer, USN, Naval Air Rocket Test Station (Lake Denmark).

**Johnson, Bernard T.,** B.S. in M.E. Flight Test Operations & Analysis Unit Chief, Boeing Airplane Co. (Wichita).

**Khosla, Gautam,** M.S.Ae.E.

**Kobernuss, Fred O.,** Air Technical Intelligence Specialist, Air Technical Intelligence Center, USAF, Wright-Patterson AFB.

**Kolve, Irving A.,** B.S.M.E., Engrg. Designer "A," Boeing Airplane Co. (Seattle).

**Lance, Godfrey N.,** Ph.D., National Academy of Sciences Research Fellow & Lecturer in Engrg., Univ. of California (Los Angeles).

**Lively, Octa D.,** B.S.M.E., Flight Test Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

**Myron, Clayton E.,** Engr.-Designer "A," Boeing Airplane Co. (Seattle).

**Nowitzky, Albin M.,** M.S. in Ae.E., Sr. Power Plant Engr., The Glenn L. Martin Co.

**Rice, Chester T.,** B.S.E.E., Sales Engr., A. & O.S. Div., General Electric Co.

**Steele, Frederick I.,** B.S. in Ae.E., Asst. Proj. Engr., McDonnell Aircraft Corp.

**Thorson, Morris H.,** B.S.M.E., Supvr., Performance & Cycle Analysis, General Electric Co. (West Lynn).

**Tuzen, Joseph B.,** M.Sc., Application Engr., Marquardt Aircraft Co.

**Werner, Jerard B.,** M.S., Thermodynamics Engr., Lockheed Aircraft Corp. (Burbank).

**Wethe, J. Duane,** M.S. Ind. Eng., Mgr., Product Service, Marketing Section, Jet Engine Dept., AGTD, General Electric Co. (Cincinnati).

**Wilson, Francis M., Jr.,** B.S. in Ae.E., Sr. Aerodynamics Engr., Lockheed Aircraft Corp.

### Transferred to MEMBER Grade

**Catchpole, Eric John,** M.Sc. in Ae.E., Struct. Analyst, Vickers Armstrongs, Ltd.

**Garcia, Victor Roger,** A.E., Stress Analyst, Douglas Aircraft Co., Inc. (El Segundo).

**Keaner, Earl R.,** B.S. in Ae.E., Aero. Research Scientist, NACA (Edwards AFB).

**Madrick, Allen H.,** M.Ae.E., Design Engr., Loads Dept., Helicopter Engrg. Div., McDonnell Aircraft Corp.

**Noll, Alan H.,** M.Sc. in Ae.E., Research Analyst, Douglas Aircraft Co., Inc. (El Segundo).

**Rathbun, Kenneth C.,** M.E., Research Assoc., Experiment, Inc.

**Roden, William Stephen,** B.S.Ae.E., Flight Test Engr., Northrop Aircraft, Inc. (Patrick AFB).

**Rogers, Arthur William,** M. of Ae.E., Aero. Engr., Hughes Aircraft Co. (Culver City).

**Schindler, Martin H.,** M. of Ae.E., Aero. Engr., Asst. Head, Flying Qualities Guided Missiles Unit, Aero & Hydro Br., Airframe Design Div., Bur. of Aero., Dept. of the Navy (Washington, D.C.).

**Smith, Dickson J.,** B.S. in Engrg., Thermodynamics Engr., Convair-San Diego Div. of General Dynamics Corp.

**Wagner, Raymond S.,** B.S.M.E., Installation Engr., AGTD, General Electric Co. (Evendale).

**White, Gerald B.,** M.S. in Ae.E., Sr. Proj. Engr., Midwest Research Institute.

**Zlotnick, Martin,** M. of Ae.E., Sr. Aerodynamicist, Republic Aviation Corp.

### Elected to Associate Member Grade

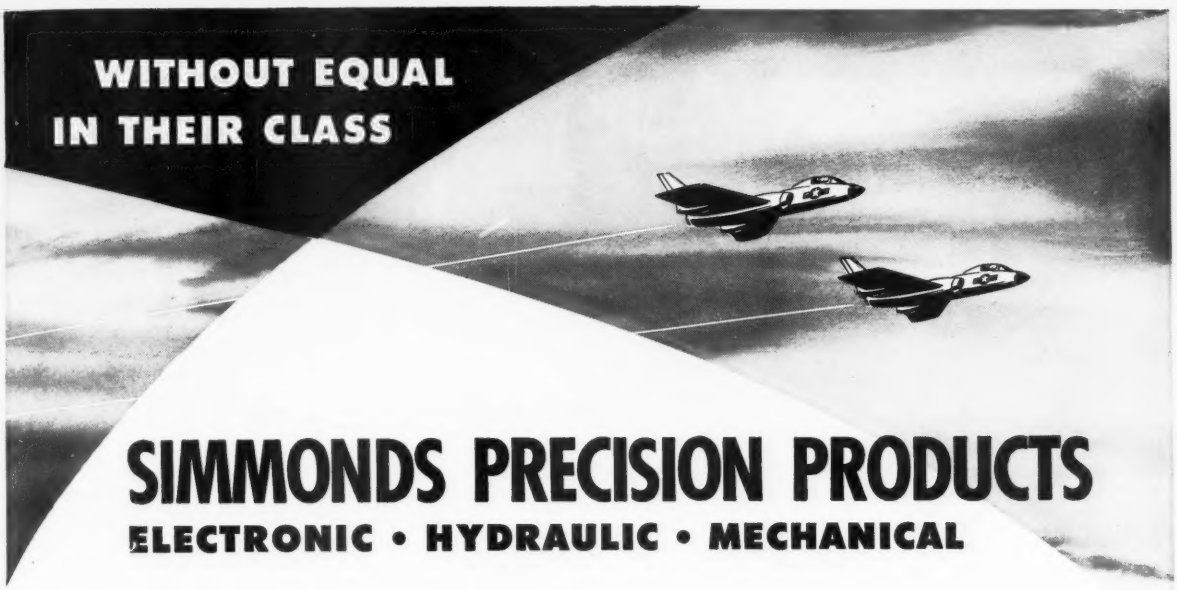
**Armstrong, Aikman, Jr.,** Sales Rep., Aerojet General Corp.

**Eddie, Albert R.,** Managing Dir. & Secy., Canadian Air Line Pilots Association.

**Proudlove, David,** Asst. Civil Air Attaché, British Embassy (Washington, D.C.).

**Renner, William B.,** A.B., Sales Engr., Aluminum Co. of America (New York).

**Ruffin, M. B.,** B.S.M.E., Dir., Customer Relations Div., Summers Gyroscope Co.

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**Scherl, Ely,** M.S., Supvr. of Engrg. Programming, Small Aircraft Engrg. Dept., General Electric Co. (Boston).

**Yoakley, William R., Jr.,** Inspection Test Pilot, North American Aviation, Inc. (Los Angeles).

### Transferred to Associate Member Grade

**Dougherty, Edwin Vernon, III,** S.B. in Ae.E., Engrg. Economist, Brown Instruments Div., Minneapolis-Honeywell Regulator Co.

### Elected to Technical Member Grade

**Goldstein, Edward,** Material Review Analyst, Republic Aviation Corp.

**Hall, Stephen,** B.Sc.M.E., Aerodynamicist "A," Ryan Aeronautical Co.

**Jones, Marion A.,** B. of C.E., Assoc. Engr., The Glenn L. Martin Co.

**Lenderman, Donald B.,** B.S. in Ae.E., Flight Test Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

**Ortman, John H.,** B.A., Assoc. Engr., Armament Section, Engrg. Dept., Douglas Aircraft Co., Inc. (Santa Monica).

**Schmidt, Craig M.,** M.S., Aerodynamicist, Bell Aircraft Corp.

**Switzer, John R.,** B.Sc.M.E., Engr., Controls & Component Analysis, AGTD, General Electric Co.

**White, Peter G.,** Aerodynamics Test Engr., A. V. Roe Canada, Ltd.

### Transferred to Technical Member Grade

**Albertini, Jack A., Jr.,** B.S., Aero. Engr., Naval Air Development Center (Johnsville, Pa.).

**Alderson, Jerry D., Jr.,** B.S., Capt. & Pilot, USAF; Aero. Engr., Wright-Patterson AFB.

**Banks, George A.,** B.S. in Ae.E., Jr. Analytical Engr., Pratt & Whitney Aircraft Div., United Aircraft Corp.

**Barte, G. R.,** B.S., Experimental Liaison Engr., Chance Vought Aircraft, Inc. (Dallas).

**Bell, William R.,** B.S. in Ae.E., Engrg. Asst. "A," Northrop Aircraft, Inc. (Hawthorne).

**Bent, Jack,** B.S. in Ae.E., Lt., Operations Officer, USN, VF-23 (San Francisco).

**Bradley, Richard G.,** B.A.E., Jr. Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

**Breen, Edward W.,** B. of Ae.E., Aerodynamicist, Gruman Aircraft Engineering Corp.

**Brown, Robert A.,** B.A.E., Engr.—Flight Test, Grumman Aircraft Engineering Corp.

**Burger, Elting G., Jr.,** B. of Ae.E., Design Engr., Gruman Aircraft Engineering Corp.

**Cassidy, Mell D.,** M.S. in Ae.E., Aerodynamicist "B," Lockheed Aircraft Corp., (Burbank).

**Champoux, Ronald J.,** B.S. in Ae.E., Engr. "B," Boeing Airplane Co. (Seattle).

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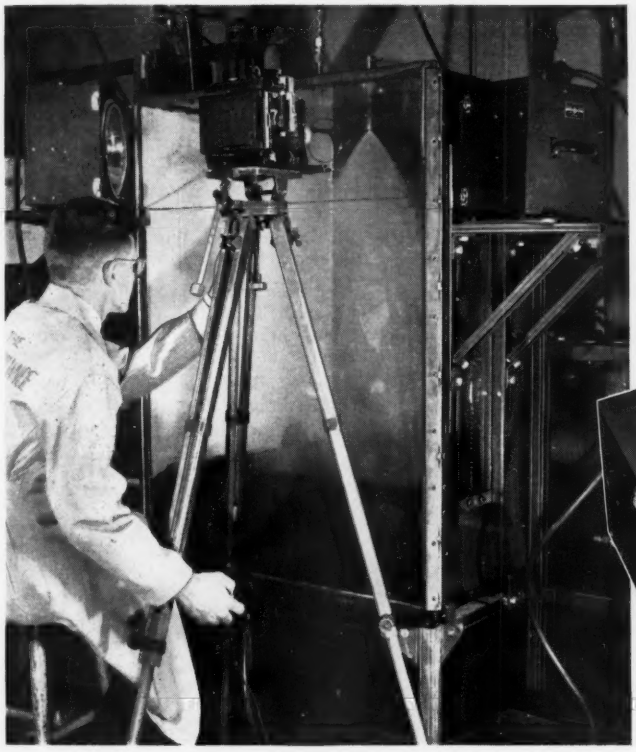

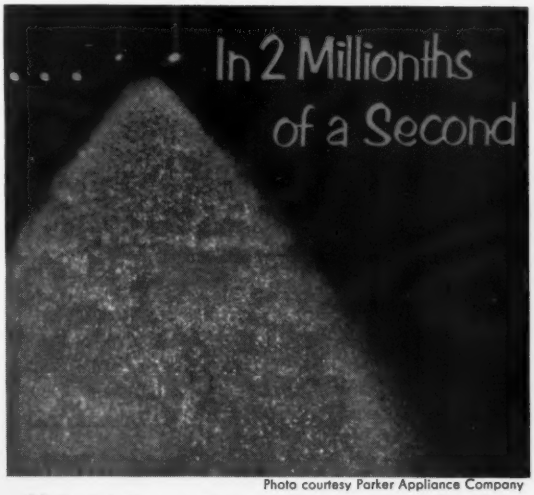

Photo courtesy Parker Appliance Company

*"Flash bulbs of 1/80 second to 1/170 second light duration would not stop the high-velocity droplets in the atomized fuel spray. A commercially available high-speed electric flash with light durations as small as 1/30,000 second was also found unsatisfactory.*

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**Christensen, M. J.,** B.S., Flight Test Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

**Cooper, James P.,** M.S.M.E., Lt., USAF; Aero. Engr., Propeller Lab., WADC, Wright-Patterson AFB.

**Dill, Alvin W.,** Maj., USAF; Aero. Engr.—Inspection, 1002nd I.G. Group, D/RMI, (Norton AFB).

**Dimmick, Leroy,** B.S. in Ae.E., Assoc. Engr., Aerodynamics Dept., The Glenn L. Martin Co.

**Doering, D. A.,** B.S., Jr. Engr., Douglas Aircraft Co., Inc. (Long Beach).

**Doughty, D. L.,** Ph.D., Research Engr., Shell Development Co.

**Dovey, Richard K.,** Design Draftsman, Bendix Aviation Corp. (Pacific Div.).

**Durner, Albert Charles,** B.A.E., Engrg. Trainee, Republic Aviation Co.

**Dwyer, Edward W.,** B.S. in Ae.E., Jr. Engr., Pratt & Whitney Aircraft Div., United Aircraft Corp.

**Fitzgerald, J. F.,** B.S., Struct. Engr. "B," McDonnell Aircraft Corp.

**Flanigan, William T.**

**Forbragd, Maurice H.,** Major, USAF; R & D Officer—Administrative, WADC, Wright-Patterson AFB.

**Francipane, J. V.,** Engr.—Design Drafting, Gary B. Gamble & Associates.

**Frey, Richard C.,** B.S. Aero.

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**Fuller, Kenneth E.,** B.S. in Ae.E., Aero. Research Intern, NACA, Langley AFB.

**Garzon, Richard,** B. of Ae.E., Detail Engr., Experimental Test Group, Allison Div., General Motors Corp.

**Graf, Edward,** B.S. in M.E., Major, USAF; Chief, Devel. Engrg. Section, Hq. WADC, Wright-Patterson AFB.

**Greeneberg, George S.,** B.S. in Ae.E., Flight Research Engr., Sikorsky Aircraft Div., United Aircraft Corp.

**Harney, Donald J.,** Capt., USAF; Aero. Engr., WADC, Wright-Patterson AFB.

**Heckel, John L.,** B.S. in Ae.E., 2nd Lt., USAF; Asst. Proj. Engr., WADC, Wright-Patterson AFB.

**Henrie, Keith L.,** B.S., Aerodynamics Engr., Douglas Aircraft Co., Inc. (El Segundo).

**Herbener, D. G.,** B.S., Pvt., USA.

**Hoak, Donald E.,** B.S., Stability & Control Engr., WADC, Wright-Patterson AFB.

**Hofmann, F. L.,** B.S. in Ae.E., Jr. Aero. Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

**Kalmus, Stuart R., Capt.,** USAF.

**Kaups, Kalle,** B.S. in Ae.E., Sr. Asst. Engr., Aero. Research Lab., Univ. of Minnesota.

**Keiser, Kenneth J.,** B.S., 1st Lt., USAF; Asst. Proj. Officer (Holloman AFB).

**Keller, Charles L.,** B.S. in Ae.E., Jr. Engr.-Aerodynamicist, Sperry Gyroscope Co. Div., The Sperry Corp.

**Kemp, James F.,** B.S. in Ae.E., Experimental Test Engr., Allison Div., General Motors Corp.

**Korsch, Donald E.,** B. of Ae.E., Test Engr., Flight Test Operations Group, Boeing Airplane Co. (Seattle).

**Lane, Richard A.,** B. of Ae.E., Jr. Aerodynamics Engr., Convair-Ft. Worth Div. of General Dynamics Corp.

**Lee, George,** M.S., Aero. Research Scientist, Ames Aero. Lab., NACA.

**Lee, Vernon A.,** B.S. in Ae.E., Research Engr., Defense Research Lab., University of Texas.

**Lindsay, T. L.,** B.S. in Ae.E., Ens., USN.

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*(Continued on page 130)*

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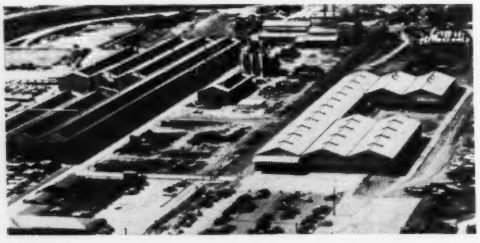

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## I. PERIODICALS AND REPORTS


Aerodynamics
- Boundary Layer & Thermoaerodynamics ... 99
- Control Surfaces ... 99
- Fluid Mechanics & Aerodynamic Theory ... 99
- Internal Flow ... 99
- Performance ... 100
- Stability & Control ... 100
- Wings & Airfoils ... 101

Aeroelasticity ... 101
Air Transportation ... 104
Airplane Design ... 104
Aviation Medicine ... 104
Computers ... 104
Electronics ... 104
- Antennas ... 104
- Circuits & Components ... 104
- Electronic Tubes ... 106
- Magnetic Devices ... 106
- Measurements & Testing ... 108
- Navigation Aids ... 108
- Networks ... 108
- Semiconductors ... 110
- Transmission Lines ... 110

Equipment
- Electric ... 110
- Hydraulic & Pneumatic ... 110

Flight Operating Problems ... 110
Flight Testing ... 110
Fuels & Lubricants ... 110
Gliders ... 110
Ice Formation & Prevention ... 110
Instruments ... 110
Lighter-Than-Air ... 114
Machine Elements ... 114
- Rotating Discs & Shafts ... 114

Materials
- Corrosion & Protective Coatings ... 116
- Metals & Alloys ... 116
- Nonmetallic Materials ... 116
- Testing ... 116

Mathematics ... 116
Meteorology ... 116
Military Aviation ... 116
Missiles ... 116
Noise Reduction ... 116
Photography ... 117

Power Plants
- Atomic ... 117
- Jet & Turbine ... 117
- Ram-Jet & Pulse-Jet ... 118
- Reciprocating ... 118
- Rocket ... 118

Production ... 118
- Metalworking ... 118
- Production Engineering ... 118

Propellers ... 118
Reference Works ... 118
Rotating Wing Aircraft ... 120
Space Travel ... 120
Structures ... 121
- Beams & Columns ... 121
- Connections ... 121
- Cylinders & Shells ... 121
- Elasticity & Plasticity ... 122
- Plates ... 122
- Wings ... 122

Thermodynamics ... 122
- Combustion ... 122

Water-Borne Aircraft ... 122
Wind Tunnels & Research Facilities ... 122


## II. BOOKS REVIEWED IN THIS ISSUE


**Introduction to Aeronautical Dynamics.** Manfred Rauscher ... 125
*Reviewed by Dr. Angelo Miele, Polytechnic Institute of Brooklyn*

**Elements of Propeller and Helicopter Aerodynamics.** Daniel O. Dommasch ... 125
*Reviewed by Eugene Stolarik, University of Minnesota*

**Singular Integral Equations.** N. I. Muskhelishvili ... 127
*Reviewed by Harry Zuckerberg, Professional Engineer*

**Book Notes ... 128**


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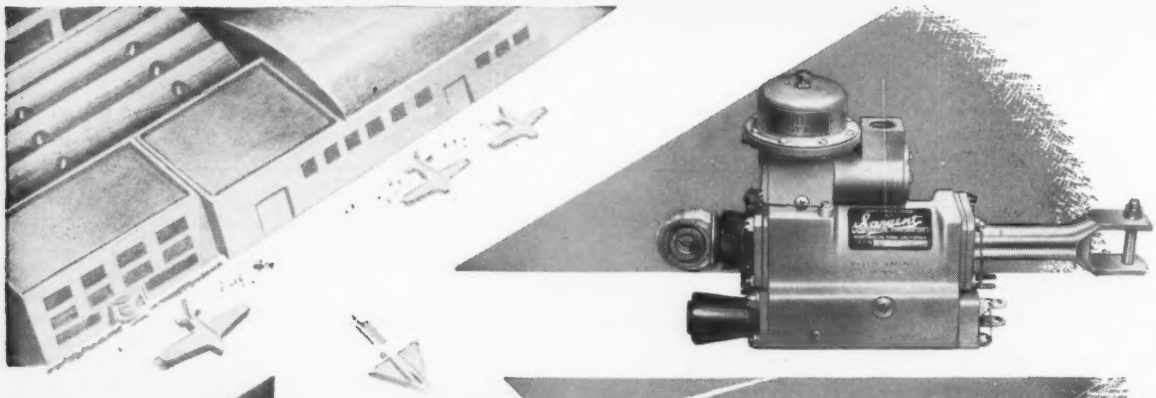

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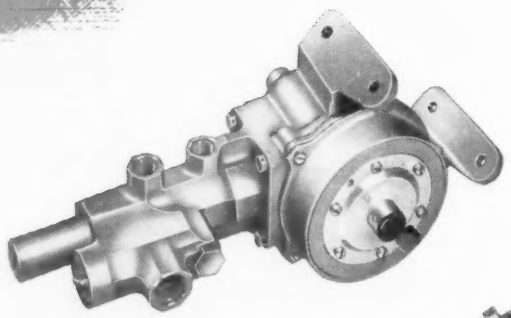

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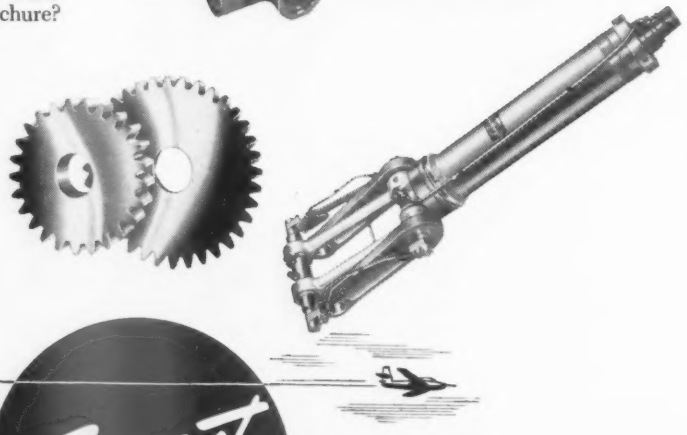

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# Aerodynamics

### *Boundary Layer & Thermoaerodynamics*

**Exact Solutions of Laminar-Boundary-Layer Equations with Constant Property Values for Porous Wall with Variable Temperature.** Patrick L. Donoughe and John N. B. Livingood. *U.S., NACA TN 3151*, Sept., 1954. 42 pp. 35 refs.

**Experimental Investigation of Heat Transfer at Hypersonic Mach Number.** R. D. DeLauer and H. T. Nagamatsu. *GALCIT Paper 327*, 1954. 16 pp. 11 refs. Determination of the heat transfer coefficients of the laminar boundary layer on a cooled flat plate at Mach Number 5.8 to obtain the plate recovery factors and the effects of condensation.

**Experiments on Aerodynamic Cooling.** Lloyd F. Ryan. *ETH Inst. für Aerodynamik (Zurich), Mitteilungen*, No. 18, 1951, p. 3. 16 refs. Measurements of surface temperature effects on various shapes behind boundary-layer separation to determine the behavior of the flow phenomena.

**Section Characteristics of an NACA 0006 Airfoil with Area Suction Near the Leading Edge.** James A. Weiberg and Robert E. Dannenberg. *U.S., NACA TN 3285*, Sept., 1954. 47 pp. 12 refs. Experimental investigation to determine the effectiveness of boundary-layer control, with measurements of the surface pressure distributions, lift, profile drag, suction requirements, and boundary-layer characteristics.

**Simplified Analysis of Turbulent Boundary-Layer Development Along Cylindrical Surfaces with Variable Free-Stream Mach Number.** Hans U. Eckert. *J. Aero. Sci.*, Oct., 1954, p. 695. 35 refs. Derivation of an approximation method from the momentum theorem to calculate the thickness of a turbulent boundary layer developed along the convex or the concave side of a smooth thermally insulated cylindrical shell placed into an isentropic stream of variable Mach Number with the axis parallel to the direction of flow.

### *Control Surfaces*

**Note on the Dynamic Characteristics of Servo-Tab Systems of Control.** D. Adamson and D. J. Lyons. *Gt. Brit., ARC R&M 2853* (Apr., 1948), 1954. 12 pp. BIS, New York. $0.90.]

**Some Aerodynamic Effects of Streamwise Gaps in Low Aspect Ratio Lifting Surfaces at Supersonic Speeds.** Z. O. Bleviss and R. A. Struble. *J. Aero. Sci.*, Oct., 1954, p. 665. 12 refs. Theoretical and experimental analysis of the characteristics of control-surface deflections in terms of a simplified configuration.

**Systematische Flugme ssungen über die Eigenschaften von Seiten-Leitwerken. I, II—Flugmessungen zur Bestimmung der Wirkungsfaktoren des Seiten-Leitwerkes.** Rudolf Schmidt. *ZFW*, May, June, 1954, pp. 113, 142. In German. Experimental flight measurements of the aerodynamic characteristics of two different fin and rudder arrangements on a twin-engined Dornier Do 217.

### *Fluid Mechanics & Aerodynamic Theory*

**Diffraction of Waves by a Wedge.** F. Oberhettinger. *Commun. on Pure & Appl. Math.*, Aug., 1954, p. 551. 21 refs. NBS-sponsored study at the Amer. U.; analyses of Green's functions of the wave equation for a wedge with an arbitrary angle for the two-dimensional case of a line source parallel to the edge of the wedge in the form of an integral representation and for the three-dimensional case of a spherical wave related to the two-dimensional case of the line source.

**Equations, Tables, and Charts for Compressible Flow.** Ames Research Staff. (*U.S., NACA TN 1428*, 1947.) *U.S., NACA Rep. 1135*, 1953. 69 pp. 20 refs. Supt. of Doc., Wash. $0.55.

**The Existence of Solitary Waves.** K. O. Friedrichs and D. H. Hyers. *Commun. on Pure & Appl. Math.*, Aug., 1954, p. 517. 11 refs. ONR-sponsored theoretical analysis of the problem to establish directly that a permanent two-dimensional irrotational flow of a fluid having a finite altitude over a horizontal bottom at rest at infinity is possible, under the assumption that the only force aside from pressure forces acting on the fluid is gravity.

**50 Jahre Aerodynamik.** Albert Betz. *ZFW*, May, 1954, p. 105. 30 refs. In German. Evaluative review of investigations into fluid motion problems and related developments.

**Laboratory Wave-Generating Apparatus.** F. Biésel, F. Suquet, and Others. (*La Houille Blanche* [France], Mar.-Apr., July-Aug., Sept.-Oct., 1951, and Dec., 1952, pp. 147, 475, 723, 779.) *U. Minn., St. Anthony Falls Hyrdaulic Lab., Project Rep. 39*, Mar., 1954. 133 pp. Translation. Design, construction, and characteristics of the experimental equipment to study wave and motion problems, with theoretical bases.

**Discrete Transitions in Turbulent Convection.** W. V. R. Malkus. *Proc. Royal Soc. (London), Ser. A*, Aug. 31, 1954, p. 185. 12 refs. ONR-sponsored experimental measurements of the heat transport and mean velocity under thermal turbulence conditions up to Rayleigh Numbers of $10^{10}$, with visual observations of the fluctuating velocity field.

**Heat Transfer from a Hemisphere-Cylinder Equipped with Flow-Separation Spikes.** Jackson R. Stalder and Helmer V. Nielsen. *U.S., NACA TN 3287*, Sept., 1954. 29 pp. 14 refs.

**The Heat Transport and Spectrum of Thermal Turbulence. I—An Upper Limit to the Heat Transport in Turbulent Convection. II—Minimum Eddy Size from the Mean Stability Conditions. III—Integrals of the Velocity and Temperature Field Due to the Convective Motion.** W. V. R. Malkus. *Proc. Royal Soc. (London), Ser. A*, Aug. 31, 1954, p. 196. ONR-sponsored theoretical investigation of various properties of the steady-state inhomogeneous turbulent convection of heat in a fluid between horizontal conducting surfaces.

**The Instability of a Layer of Fluid Heated Below and Subject to the Simultaneous Action of a Magnetic Field and Rotation.** S. Chandrasekhar. *Proc. Royal Soc. (London), Ser. A*, Aug. 31, 1954, p. 173. USAF-supported investigation at the U. of Chicago.

**Existence and Uniqueness of a Subsonic Flow Past a Given Profile.** Lipman Bers. *Commun. on Pure & Appl. Math.*, Aug., 1954, p. 441. 47 refs. ONR-sponsored development of an analytical formula to solve the basic homogeneous Neumann problem for a quasi-linear elliptic equation in an infinite region under the condition that the solution possess a prescribed singularity at infinity.

**The Rapid, Accurate Prediction of Pressure on Non-Lifting Ogival Heads of Arbitrary Shape, at Supersonic Speeds.** B. W. Bolton-Shaw and H. K. Zienkiewicz. *Gt. Brit., ARC CP 154* (June 23, 1952), 1954. 56 pp. 12 refs. BIS, New York. $1.25.

**Transonic Flow Past Cone Cylinders.** George E. Solomon. *U.S., NACA TN 3213*, Sept., 1954. 56 pp. 32 refs. Theoretical and experimental investigation of the basic problem, with a development of an approximate solution of the axially symmetric transonic equations valid for a semi-infinite cone.

**Unsteady Cavitating Flow Past Curved Obstacle.** L. C. Woods. *Gt. Brit., ARC CP 149* (Mar. 26, 1953), 1954. 9 pp. BIS, New York. $0.30.

### *Internal Flow*

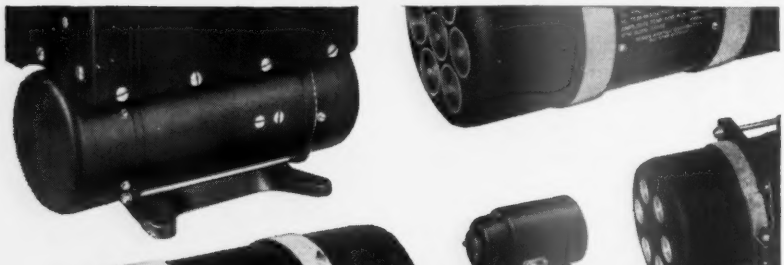
**Convective Heat Transfer to Gas Turbine Blade Surfaces.** D. G. Wilson and J. A. Pope. *The Engr.*, Aug. 27, 1954, p. 301. Abridged. Experimental investigation of the variables of the blade's Reynolds Number and the incident angle of the air stream with the air-temperature ratio kept at near unity; includes a correlation of results with values obtained by available theoretical methods.

**Ebene Plattengitter bei Überschallgeschwindigkeit.** Rashad M. El Badrawy. *ETH Inst. für Aerodynamik (Zurich), Mitteilungen*, No. 19, 1952. 90 pp. In German. Theoretical and experimental investigation including: calculation of the lift and drag coefficients for a flat plate at a 1.20—10 Mach Number range for different angles of incidence, taking into account the exact nature of flow over both sides of the plate; development of a method to calculate the lift and drag coefficients for a cascade of flat plates; determination of an analytical solution of the problem of the interaction between shock and expansion waves; formulation of a linearized theory for supersonic flow through a cascade of flat plates; application of a definition for the efficiency of cascade flows without friction to the estimation of the efficiency of a supersonic propeller.

**An Experimental Study of Three-dimensional High-Speed Air Conditions in a Cascade of Axial-flow Compressor Blades.** K. W. Todd. *Gt. Brit., ARC R&M 2792* (Oct., 1949), 1954. 34 pp. BIS, New York. $2.25. Use of optical and physical methods in a high-speed wind tunnel to study the flow characteristics.

**A Note about Secondary Circulation in two Dimensional Flow.** Shintarō Ātsuka. *J. Japan Soc. Aero. Eng.*, Aug., 1954, p. 191. In Japanese.

**The Thermodynamics of Frictional Resisted Adiabatic Flow of Gases Through**



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**Ducts of Constant and Varying Cross Section.** W. R. Thomson. *Gt. Brit., ARC CP 158* (Sept., 1952), 1954. 44 pp. BIS, New York. $1.25.

**A Theoretical Note on Effusion Cooled Gas Turbine Blades.** R. Staniforth. *Gt. Brit., ARC CP 165*, 1954. 49 pp. 37 refs. BIS, New York. $1.15. Use of an approximate method to solve the dynamic and thermal boundary layer equations for two-dimensional isothermal incompressible laminar flow over semi-infinite wedges for a range of wedge angles and injection quantities.

**Air Intake Efficiency.** F. B. Greatrex. *J. RAeS*, Sept., 1954, p. 639. Flow and design factors affecting axial compressor characteristics related to jet engine performance.

**Berechnungsmethoden von Lavaldüsen auf Grund eines Formelsystems für die Strömung in der Düsenkehle.** Wolfgang Haack and Jürgen Zierep. *ZFW*, Feb., 1954, p. 41. In German. Use of the "Method of Characteristics" to calculate the parallel flow in a symmetrical circular nozzle, the ideal flow conditions in the presence of a source in a conical nozzle, and the flow round a plane bent.

**Experiments on the Flow into a Swept Leading-edge Intake at Zero Forward Speed with Notes on the Wider Uses of a Slotted Intake.** J. Seddon and W. J. G. Trebble. *Gt. Brit., ARC R&M 2909* (Jan., 1951), 1954. BIS, New York. $1.25.

**Flow Separation in Overexpanded Supersonic Exhaust Nozzles.** Martin Summerfield, Charles R. Foster, and Walter C. Swan. *Jet Propulsion*, Sept.-Oct., 1954, p. 318.

*Performance*

**Performance Characteristics of Jet Transports.** G. S. Schairer and M. L. Olason. *Western Av.*, Oct., 1954, p. 14. Includes factors of take-off speeds, cruising capabilities, and flight and power criteria.

*Stability & Control*

**An Investigation into the Rolling Power and Aileron Reversal Characteristics of Swept Wings.** A. V. Coles and R. J. Margetts. *Gt. Brit., ARC CP 159*, 1954. 28 pp. BIS, New York. $0.65. Experimental tests using wings of constant span, aspect ratio, and area, and with sweep angles from 15° forward sweep to 60° backward sweep.

**On the Dynamics of the Aeroplane and Non-Riemannian Geometry. I—Aerodynamical Terms in the Equations of Motion. II—Discussion of the Equations of Small Disturbances.** Kazuo Kondo. *J. Japan Soc. Aero. Eng.*, July, Aug., 1954, pp. 161, 193.

**La Stabilité Transversale de Vol et Quelques Recherches de l'O.N.E.R.A.** Maurice Roy. *France, ONERA Pub. 69*, 1954. 28 pp. In French. Review of theoretical and experimental ONERA investigations to study techniques and instrumentation for the in-flight rolling and other stability problems.

**Systematisch-kritische Beispielrechnungen zur Seitenstabilität der Flugzeuge.** H. Scharn. *ZFW*, Mar.-Apr., 1954, p. 57. 14 refs. In German. Study

of the lateral stability problem by means of calculations based on the general equations of motion of a rigid body moving freely through space under the effects of aerodynamic and gravitational forces.

**Theoretical Analysis of an Airplane Acceleration Restrictor Controlled by Normal Acceleration, Pitching Acceleration, and Pitching Velocity.** Christopher C. Kraft, Jr. *U.S., NACA TN 3243*, Sept., 1954. 42 pp. Investigation of the stability and control problem utilizing data obtained with an analog computer simulating dynamic characteristics.

**Über die Bewegungs- und Störungsgleichungen in einem flugzeugfesten Koordinatensystem.** Werner Schulz. *ZFW*, July, 1954, p. 157. 15 refs. In German. Application of the Laplace transformation to the equations covering disturbances in the motion and stability problems of an airplane.

*Wings & Airfoils*

**The Effect of a Small Protuberance on Potential Flow Past an Aerofoil.** H. C. Levey. *Australia, ARL AN 134*, June, 1954. 13 pp.

**Effect of Leading-Edge Separation on the Lift of a Delta Wing.** C. E. Brown and W. H. Michael, Jr. *J. Aero. Sci.*, Oct., 1954, p. 690.

**Experimental Investigation of Influence of Edge Shape on the Aerodynamic Characteristics of Low-Aspect-Ratio Wings at Low Speeds.** G. E. Bartlett and R. J. Vidal. *Cornell Aero. Lab. Rep. CAL-62*, June, 1954. 26 pp. 30 refs.

**An Investigation of the Aerodynamics of Sharp Leading-Edge Swept Wings at Low Speeds.** C. E. Pappas and A. E. Kunen. *J. Aero. Sci.*, Oct., 1954, p. 649. 12 refs. Three-dimensional flow study to determine the effects and characteristics of the spiral-conical vortex formed at the leading-edge.

**A New Law of Similarity for Profiles, Valid on the Transonic Region.** K. Oswatitsch. *Gt. Brit., ARC R&M 2715* (June, 1947), 1954. 12 pp. BIS, New York. $0.90.

**On the Application of Transonic Similarity Rules to Wings of Finite Span.** John R. Spreiter. (*U.S., NACA TN 2726*, 1952.) *U.S., NACA Rep. 1153*, 1953. 21 pp. 35 refs. Supt. of Doc., Wash. $0.25. Discussion of aerodynamic characteristics of wings from the point of view of a unified small perturbation theory for subsonic, transonic, and supersonic flows about thin wings.

**Sul Problema dell'Ala Triangolare a Diedro Qualsiasi a Velocità Supersonica, con Incidenza e Deriva Piccole del Prim'-Ordine (On the Problem of Triangular Wing With Whatever Dihedral and First Order Incidence and Yaw Angles at Supersonic Speeds).** Silvio Nocilla. *L'Aerotecnica*, June, 1954, p. 126. In Italian. Approximate determination of the aerodynamic coefficients of the pressures on the wing by the use of the linearized potential theory solving a double-mixed equation of Dirichlet-Neuman in a two-fold connected field.

**Transonic Flow Past Swept and Unswept Wings Between Parallel Walls.** Willi Jacobs. *Sweden, Flygtekniska Försöksanstalten FFA Medd. 55*, 1954. 34 pp. 20 refs.

**Velocity Distribution on Thin Tapered Wings and Fore-and-aft Symmetry and Spanwise Constant Thickness Ratio at Zero Incidence.** S. Neumark and J. Collingbourne. *Gt. Brit., ARC R&M 2858* (June, 1951), 1954. 43 pp. BIS, New York. $2.65.

**Application of Two-Dimensional Vortex Theory to the Prediction of Flow Fields Behind Wings of Wing-Body Combinations at Subsonic and Supersonic Speeds. Appendix A—Nonequivalence of Wing Span Loading and Circulation Distribution Γ (y) Along the Trailing Edge of a Wing. Appendix B—Correction of Slender-Body Theory to Account for Moderate Aspect Ratio.** Arthur Wm. Rogers. *U.S., NACA TN 3227*, Sept., 1954. 91 pp. 24 refs.

**Investigation of Lift, Drag, and Pitching Moment of a 60° Delta-Wing-Body Combination (AGARD Calibration Model B) in the Langley 9-Inch Supersonic Tunnel.** August F. Bromm, Jr. *U.S., NACA TN 3300*, Sept., 1954. 18 pp.

**The Drag Increase at High Subsonic Speeds.** K. Oswatitsch. *Gt. Brit., ARC R&M 2716* (Oct., 1947), 1954. 16 pp. 12 refs. BIS, New York. $1.25.

**Ebene Plattengitter bei Überschallgeschwindigkeit.** Rashad M. El Badrawy. *ETH Inst. für Aerodynamik (Zurich), Mitteilungen*, No. 19, 1952. 90 pp. In German. Theoretical and experimental investigation including: calculation of the lift and drag coefficients for a flat plate at a 1.20–10 Mach Number range for different angles of incidence, taking into account the exact nature of flow over both sides of the plate; development of a method to calculate the lift and drag coefficients for a cascade of flat plates; determination of an analytical solution of the problem of the interaction between shock and expansion waves; formulation of a linearized theory for supersonic flow through a cascade of flat plates; application of a definition for the efficiency of cascade flows without friction to the estimation of the efficiency of a supersonic propeller.

**Maximum Lift for Landing of Swept Wing Aeroplanes.** Hans Olof Palme. *SAAB TN 17*, Apr. 20, 1953. 14 pp. 30 refs.

**Methods of Approaching an Accurate Three-dimensional Potential Solution for a Wing.** H. C. Garner. *Gt. Brit., ARC R&M 2721* (Oct., 1948), 1954. 19 pp. 14 refs. BIS, New York. $1.25. Study of the vortex-sheet theory to determine the distribution of lift on a finite wing.

**A Simple Method of Computing $C_D$ from Wake Traverses at High-subsonic Speeds.** J. S. Thompson. *Gt. Brit., ARC R&M 2914* (Dec., 1944), 1954. 12 pp. BIS, New York. $0.90. Graphical calculation of the profile drag, with a summary of the standard theory and equations and details of the construction of the charts.

**Summary of Stalling Characteristics and Maximum Lift of Wings at Low Speeds.** Hans Olof Palme. *SAAB TN 15*, Apr. 10, 1953. 21 pp. 35 refs.

**Summary of Wind Tunnel Data for High-Lift Devices on Swept Wings.** Hans Olof Palme. *SAAB TN 16*, Apr. 20, 1953. 18 pp. 36 refs.

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## Aeroelasticity

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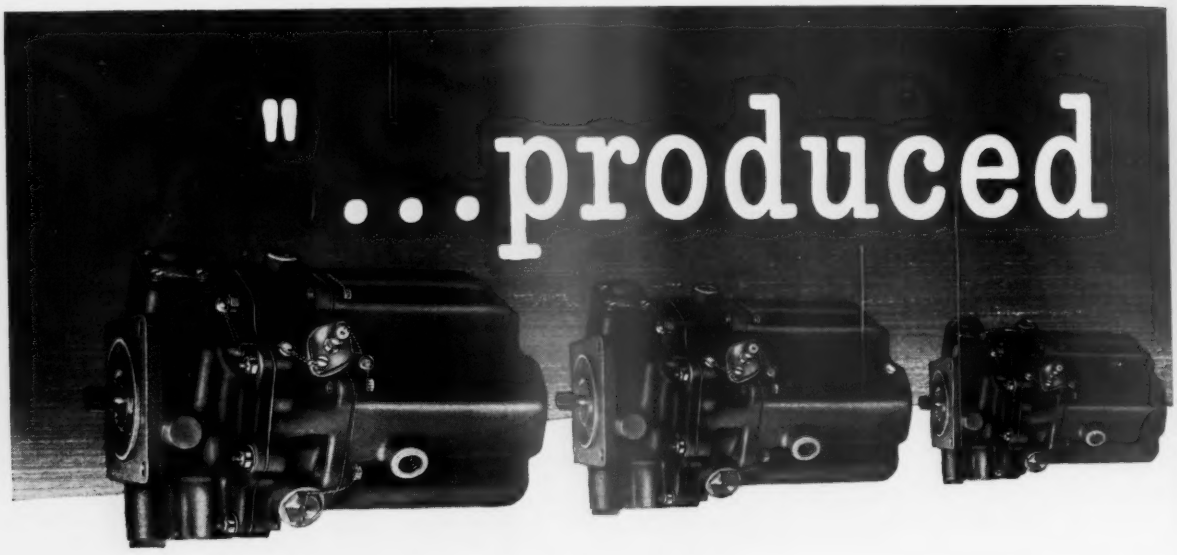


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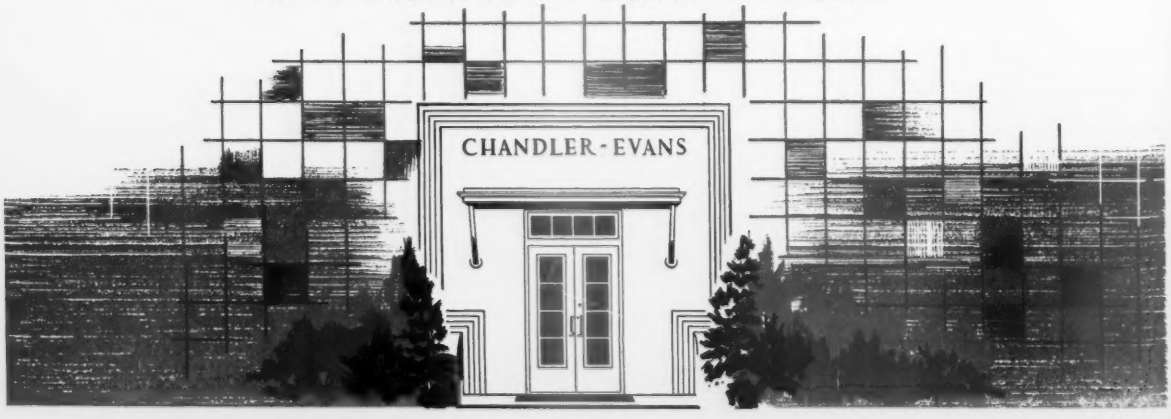

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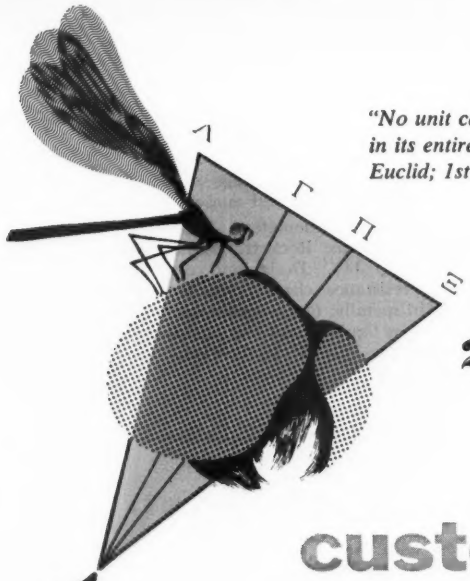

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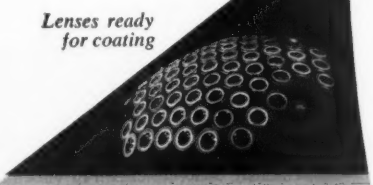

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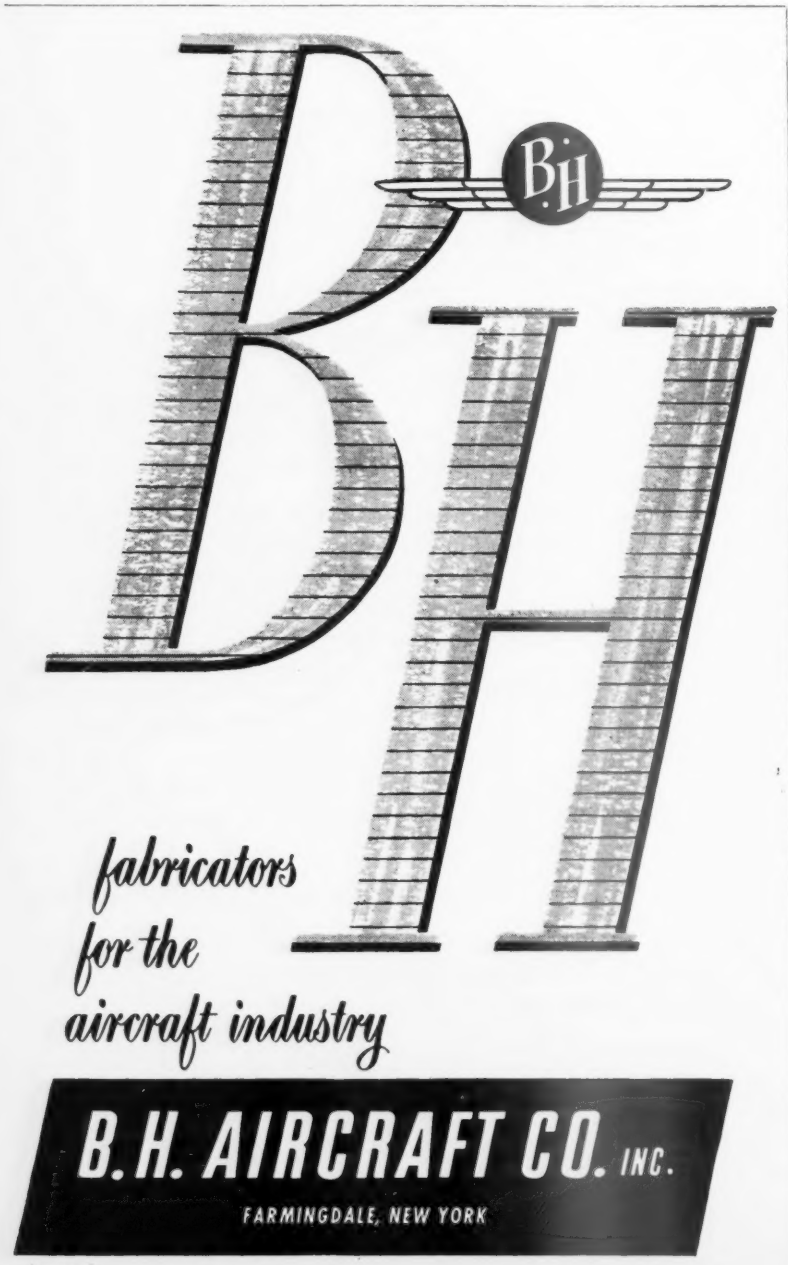


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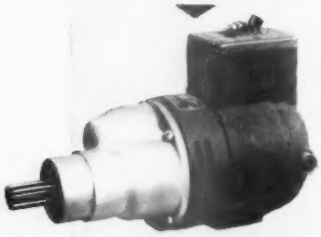

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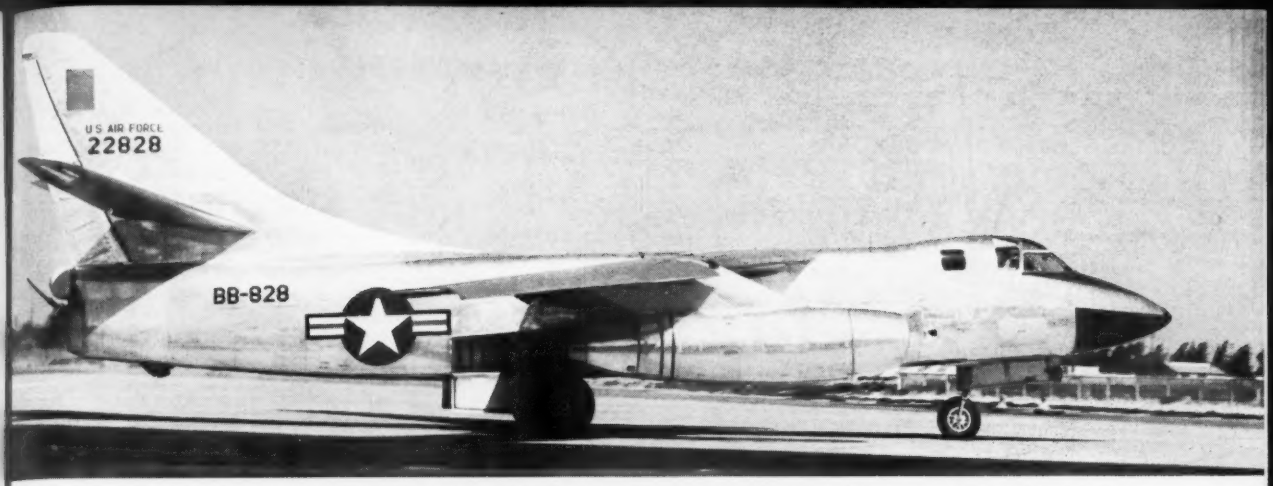
Douglas B-66 takes off at Long Beach, California, for its test run. Its electrical system was designed by G-E application engineers to deliver rated load with 80° C cooling air.

GENERAL ELECTRIC




Side view of bomber shows sleek lines. It is first production aircraft to have an elevated ambient temperature a-c electric system.

# Latest Air Force bomber has new G-E engineered power-generating electric system

## NEW GENERAL ELECTRIC ENGINEERED SYSTEM MEETS DOUGLAS B-66 OPERATIONAL DEMANDS FOR HIGHER AMBIENT TEMPERATURES

A new a-c electric power-generating system has been developed by General Electric, and is now operating on the Air Force's newest light bomber, the Douglas B-66. The system consists of three major components: high-efficiency alternators, static voltage regulators, and generator control and protective panels.

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The new equipment begins operating as soon as the pilot starts the engine. The system contains only two toggle switches, which may remain "on" at all times, even when a fault develops. This eliminates a series of pilot functions and sharply reduces the time required to become airborne. Under normal conditions, fault clearing and resetting are fully automatic.

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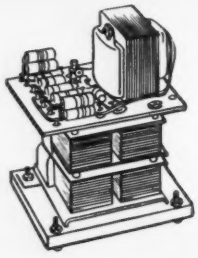
# GENERAL ELECTRIC

Static regulator (left) maintains constant alternator output voltage. Control and protective panel (right) helps locate and isolate faulty generation.

New G-E high-efficiency a-c generator has no harmonic over 1%; produces full rating when exposed to high temperatures in high speed aircraft.

Tests of system showed better protection against over voltage, over and under excitation, ground fault, anti-cycling, difference current, and open phase.



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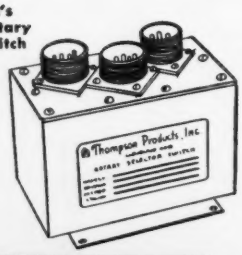


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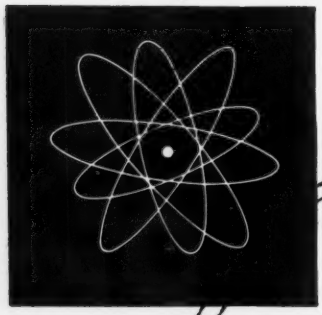

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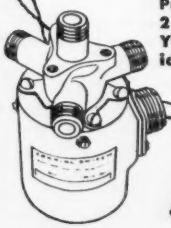

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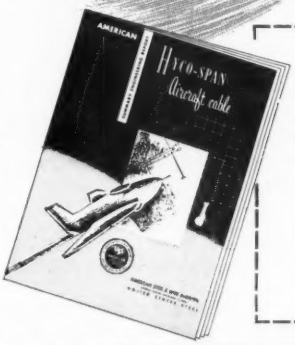


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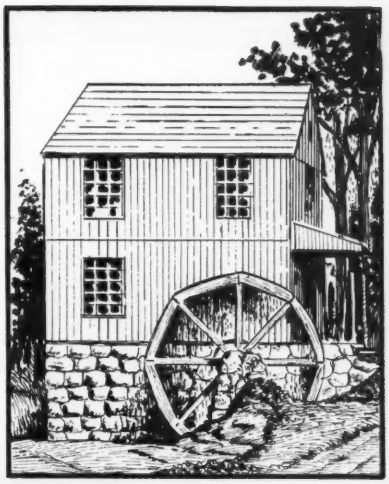

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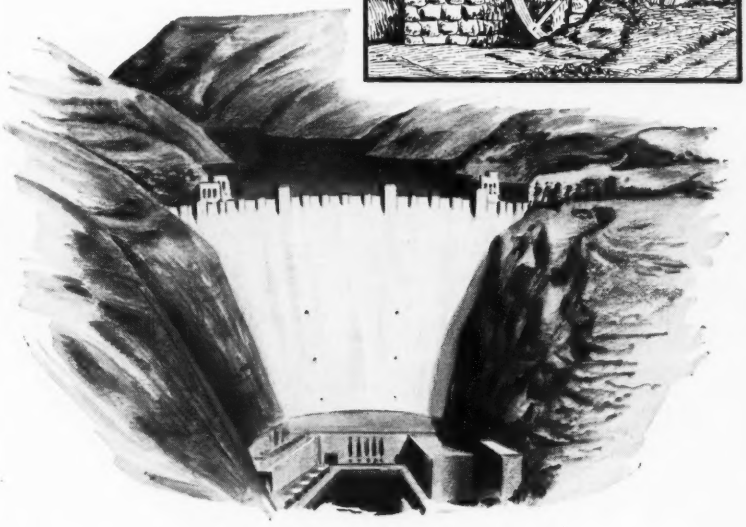

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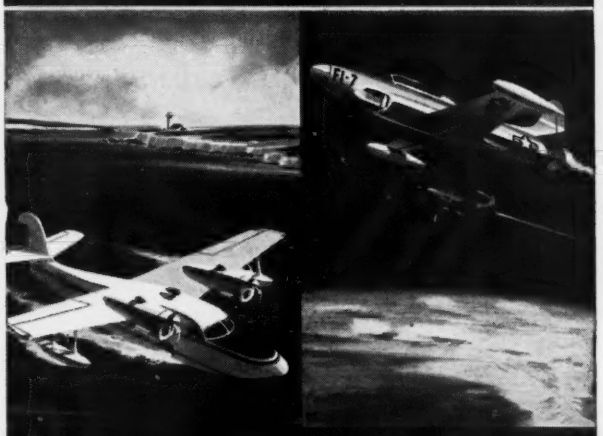

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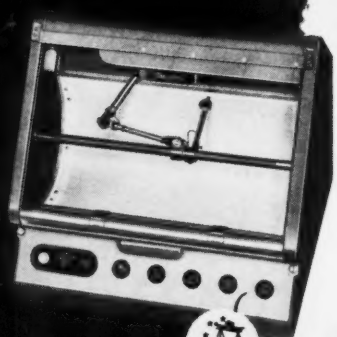

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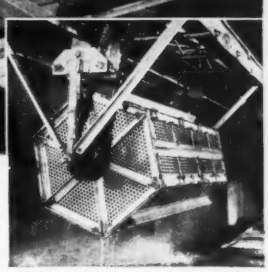

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## Wind Tunnels & Research Facilities

**The High-Speed Laboratory of the Aerodynamics Division, N.P.L. I—Description of the Installation. II—Experimental Techniques. III—Experimental Results.** D. W. Holder. *Gt. Brit., ARC R&M 2560* (Dec., 1946), 1954. 277 pp. 222 refs. BIS, New York. $14.60. Review of investigations, description of the wind tunnels, and experimental techniques and apparatus to study flow problems, with a comprehensive bibliography.

**Laboratory Surface Wave Equipment; A Summary of Literature.** James Ross and C. E. Bowers. *U. Minn., St. Anthony Falls Hydraulic Lab., Project Rep. 38*, Nov., 1953. 124 pp. 163 refs. Translation.

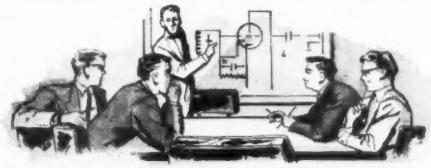
**Laboratory Wave-Generating Apparatus.** F. Biésel, F. Suquet, and Others. (*La Houille Blanche* [France], Mar.-Apr., July-Aug., Sept.-Oct., 1951, and Dec., 1952, pp. 147, 475, 723, 779.) *U. Minn., St. Anthony Falls Hydrauloc Lab., Project Rep. 39*, Mar., 1954. 133 pp. Translation. Design, construction, and characteristics of the experimental equipment to study wave and motion problems, with theoretical bases.

**Model Tests on an Air Interchange System for Removing Engine Exhaust Products from a Wind Tunnel.** K. W. Newby, E. G. Barnes, and D. W. Bottle. *Gt. Brit., ARC R&M* 2639 (Mar., 1948), 1954. 32 pp. BIS, New York. $2.00.

**Note on an Application of the Tilting Plate Method of Mach Number Variation for Wind Tunnel Tests at Low Supersonic Speeds.** J. Seddon and L. Haverty. *Gt. Brit., ARC CP 168* (Mar., 1953), 1954. 18 pp. BIS, New York. $0.50.

**Schlieren Methods for Observing High-speed Flows. I—General Considerations, and Methods for Two-dimensional Flow. II—Methods for Three-dimensional Flow.** D. W. Holder and R. J. North. *Gt. Brit., ARC CP 167* (July 1, 1953), 1954. 27 pp. 49 refs. BIS, New York. $0.65.

**Starting and Operating Limits of Tow Supersonic Wind Tunnels Utilizing Auxiliary Air Injection Downstream of the Test Section.** Henry R. Hunczak and Morris D. Rousso. *U.S., NACA TN 3262*, Sept., 1954. 28 pp.



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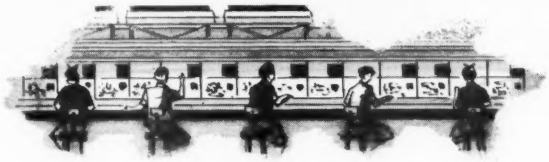
Design



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# Aeronautical Reviews — BOOKS

## Introduction to Aeronautical Dynamics

**By Manfred Rauscher. New York, John Wiley & Sons, Inc., 1953. 664 pp., diagrs., figs. $12.**

Professor Manfred Rauscher is to be congratulated for his excellent contribution to aeronautical literature. *Introduction to Aeronautical Dynamics* is the result of two decades of writing in connection with the author's teaching position at Massachusetts Institute of Technology. This interesting and unique book gives a combined account of the kinematics and dynamics of particles, discrete systems, and continuous systems.

Painstaking attention has been devoted to clarifying the basic ideas of solid and fluid dynamics. Fundamental principles are emphasized through rigorous discussions. Typical samples of the character of the book are the author's considerations on the concept of continuum and the alternative derivations of the continuity and momentum equations of fluid mechanics.

Many illustrative examples of aeronautical interest are given. As a consequence, the work will appeal to practically minded students. In connection with the undergraduate character of the book, vector notations are avoided. In spite of that and despite his own personal inclination in favor of vectors, this reviewer believes that *Introduction to Aeronautical Dynamics* may also be a useful element of consultation for graduate students and aeronautical engineers.

As it is unavoidable, many topics have been omitted, such as the theory of thin airfoils and the dynamics of compressible flows in more than one dimension. Professor Rauscher feels compelled to explain in the preface the reason for these omissions. In this connection the reviewer believes that a book is to be judged essentially on the basis of its actual content, and he personally thinks that Professor Rauscher's effort is, because of extension and depth, valuable and worthy in many respects.

The future reader may better understand the character of the work through a detailed description of the various component parts.

The first chapter deals with the kinematics of a point. The analytical relationships between displacement, velocity, and acceleration are derived for Cartesian, cylindrical, and spherical coordinate systems.

Chapter II deals with the dynamics of a particle, for the two cases of constant mass and variable mass. In addition to the explanation of general principles, several applications of aeronautical or astronomical interest are carried out.

Chapter III refers to the dynamics of discrete systems. The next chapter deals with the case of continuous systems.

Chapter V is concerned with the stream function and the velocity potential, while Chapter VI refers to the motion of a fluid about simple bodies. The concepts of source, sink, and vortex are introduced.

Chapter VII has a mathematical character, dealing with the theory of a complex variable and with the conformal transformation. In the next chapter two-dimensional wings are treated. Joukowski, von Mises, and Kármán-Trefftz profiles are discussed, and the Kutta-Joukowski condition is introduced.

Chapter IX is concerned with three-dimensional wings. Prandtl lifting line theory is discussed, and the solution of the equations connecting circulation and downwash is carried out with the help of Fourier series.

Chapter X deals with viscosity effects and applications of dimensional analysis to viscous flows and theory of models.

Chapter XI refers to the kinematics of rigid bodies, while Chapter XII considers the dynamics of rigid bodies. Several applications of aeronautical interest are carried out, such as gyroscopic effects associated with propellers.

The book is concluded with two chapters on oscillations—Chapter XIII dealing with systems having one degree of freedom and Chapter XIV concerning systems with more than one degree of freedom.

Dr. Angelo Miele
Research Assistant Professor of
Aeronautical Engineering
Aerodynamics Laboratory
Polytechnic Institute of Brooklyn

## Elements of Propeller and Helicopter Aerodynamics

**By Daniel O. Dommasch. New York, Pitman Publishing Corporation, 1953. 178 pp., diagrs., figs. $4.50.**

The recent successful use of helicopters in military and commercial service has resulted in considerable interest in this new means of air transportation as well as in a demand for engineers familiar with helicopter theory.

Therefore, it is gratifying to find a text such as Professor Dommasch's *Elements of Propeller and Helicopter Aerodynamics*, published by Pitman Publishing Corporation. I found it especially interesting, having introduced here at the University of Minnesota a course entitled "Airscrew Propulsion" for the purpose of familiarizing students with the fundamental principles of both propeller and helicopter theory. Professor Dommasch's book combines the topics of propellers and helicopters and acts as an introduction to the increasingly important field of the helicopter. It is a simple and well-integrated text of six chapters, of which the first three are devoted primarily to propeller theory and the last three to the extension of these theories to helicopters.

In Chapter 1 the author lists the terminology and briefly reviews some fundamental laws—such as the law of equilibrium, Newton's second law, conservation of energy, conservation of mass, conservation of momentum, and perfect gas law—which form the basis for further developments. In this chapter he also discusses the propeller as a thrust-producing device through momentum considerations.

In Chapter 2 the author discusses the principal theories available for analytical prediction of propeller characteristics—such as simple blade-element theory and Glauert's vortex theory with modifications by Goldstein, Lock, and Theodorsen—giving a good simple résumé of all these theories. In certain cases, such as the Goldstein theory, the author eliminates some of the mathematics used by Goldstein in his analysis but presents its principal results. This chapter also includes good illustrative examples of application of both vortex and Goldstein's theories. In addition, it shows the physical basis of defining the propeller coefficients, with some discussion of the effects of compressibility on the incompressible theories of propeller action.

Chapter 3 considers such items as the selection of the propeller for a given airplane with an illustrative example—the ducted propeller—and the interference effects due to the presence of a wing or nacelles. It also discusses the effects of yaw or pitch upon the propeller forces,

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producing a normal force and a moment when the free-stream flow is not along the propeller axis, and points out the similarity between a yawed propeller and a helicopter rotor in forward flight. Chapter 4 shows the application of the propeller theory to the determination of the performance of a helicopter in vertical flight. Here, the author develops procedures for rapid performance calculations of the helicopter in vertical ascent, vertical descent, and hovering. He does not account for the effects of fuselage interference on efficiency, arguing that the results are sufficiently close to those obtained experimentally.

Chapter 5 uses the concept of average flow through the rotor of a forward-moving helicopter rotor to obtain the equations for the rotor coefficients in forward flight. Utilizing these coefficients and the Wald's method of analysis, the author develops an approximate method for evaluation of the helicopter's forward-flight performance.

Chapter 6 discusses the nature of helicopter stability and control. It shows the relationship of flapping and feathering characteristics of the rotor to the stability and control. It also points out the effect of off-set hinges, stabilizing bars, and contol rotors. This chapter deals only with static stability, as would be expected in an introductory text, omitting dynamic longitudinal stability as beyond the scope of this book.

It is a readable and well-written text and includes a number of well-selected problems to be solved by the student. The subject matter is well organized and the presentation of material is consistently clear and simple. Throughout the text the author manages, in a concise way, to help the reader reach further understanding of the problems involved. This is an important and commendable feature.

It seems somewhat regrettable that the book does not refer to or discuss the close relationship between aerodynamics and the structural and vibrational aspects of helicopters.

It is expected that Professor Dommasch's textbook will be a useful addition to the literature available at present for the training and indoctrination of new men in the field of aerodynamic helicopter theory.

EUGENE STOLARIK
Associate Professor of Aeronautical Engineering
University of Minnesota

### Singular Integral Equations

**By N. I. Muskhelishvili. Translated from the Russian by J. R. M. Radok. Groningen, Nethlands, P. Noordhoff, Ltd., 1953. 447pp., illus., diagrs., figs. $8.00.**

This treatise presents a thorough treatment of the basic principles of the theory of singular equations which in recent years has assumed increasing importance in applications to problems in theoretical mechanics such as elasticity, hydromechanics, and other branches of mathematical physics. The

**Jim Hong,** Aerodynamics Division head, discusses results of high speed wind tunnel research on drag of straight and delta wing plan forms with Richard Heppe, Aerodynamics Department head (standing), and Aerodynamicist Ronald Richmond (seated right).


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book is accessible to those who are acquainted with the basic theory of functions of a complex variable and the theory of Fredholm integral equations.

Muskhelishvili has selected and summarized the results of numerous outstanding Russian papers in a form that enables the reader to examine and become readily acquainted with the theory and applications of one-dimensional singular equations involving Cauchy principal values. The limitation to the treatment of only the one-dimensional singular equations is necessary since this theory can be presented in a finished form whereas the theory of the multidimensional equations of corresponding form is still far from completion. (Some references to the literature dealing with the latter case are included.)

The contents are divided into six parts, beginning with the introduction to the elementary theory of the Cauchy integrals together with a number of direct simpler applications. It is shown that this theory is particularly simple and effective when considering the solution of a boundary problem of the theory of functions of a complex variable (called the Hilbert problem). The solution thus obtained leads to the basic development of the theory of singular equations.

The balance of the contents is devoted to applications to the solutions of more complicated boundary problems, in particular, to problems encountered in potential theory, elasticity, and in hydromechanics.

This very impressive monograph is a valuable addition to mathematical literature. The translator, who should be highly commended for his excellent treatment, adds to the richness of the subject matter with the introduction of modifications and the addition of footnotes and indices which increase its readability and usefulness. The publishers should also be commended for the excellent appearance of the book.

HARRY ZUCKERBERG
Professional Engineer
New York, N.Y.

## Book Notes

### AERODYNAMICS

**Elementary Fluid Mechanics.** John K. Vennard. 3rd Ed. New York, John Wiley & Sons, Inc., 1954. 401 pp., illus., diagrs., figs. $5.50.

In order to make this edition more useful, Professor Vennard has extended its topical coverage by about 10 per cent. Thoroughly revised, the book includes a new introductory chapter of generalizations on the subject of one-dimensional fluid flow. Three hundred new problems have been added.

**Proceedings of the Second Midwestern Conference on Fluid Mechanics;** held at The Ohio State University, March 17–19, 1952. (Engineering Experiment Station, Bulletin No. 149, September, 1952.) Columbus, Ohio, College of Engineering, The Ohio State University, 1952. 529 pp., illus., diagrs., figs. $6.00.

Forty-seven papers are reproduced in this volume, grouped under the following broad subjects: Turbulence, Hydraulics and Incompressible Flow, Compressible Flow, Convective Phenomena and Heat Transfer, Astrophysics, and Combustion.

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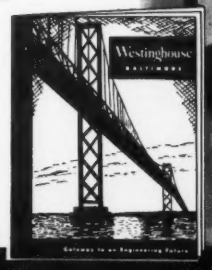


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### ELECTRONICS

**Airborne Electronics Digest:** A Compendium of Technical Papers Exemplifying Progress in the Field of Airborne Electronics, presented at the National Conference on Airborne Electronics, May 10–12, 1954, Dayton, Ohio. Dayton Section, Institute of Radio Engineers, 1954. 292 pp., illus., diagrs., figs. $4.00.

This book, the third volume of its kind in the history of the National Conference on Airborne Electronics, has this year been given the name *Airborne Electronics Digest*. It is the objective of the Conference that this publication will serve as a journal on air-borne electronics and that each successive issue will constitute a useful summation or "digest" of advances made in this rapidly progressing branch of the electronics field. One hundred and six papers are published in this volume, either in full or in summary form.

### METALS AND ALLOYS

**The Light Metals Handbook.** George A. Pagonis. New York, D. Van Nostrand Company, Inc., 1954. 2 Vols. 199 and 185 pp., figs. $8.50.

This book simplifies the task of gathering facts and information on aluminum- and magnesium-base alloys. It was written to serve aircraft, industrial, and civil engineers, fabricators, and light-metal foundries, as well as men developing engineering specifications. Concise yet comprehensive analysis of aluminum and magnesium alloys is presented from which correct selection can be made by comparison of alloying stabilities and chemical reaction characteristics and by following through the procurement stages to actual testing. Included for various classes of alloy materials are data on mechanical properties at room, low, and elevated temperatures; on physical properties; on choice of alloy, casting, formability, heat treatment, corrosion, machinability; on joining methods; and on detailed properties of individual compositions.

This book is published in two volumes. Volume I covers the text, and volume II consists of the tables to be used simultaneously with the text. The two-volume make-up allows the reader to have conveniently before him any specific table referred to in the text. The author is associated with the Light Metals Research Laboratory, San Jose, Calif.

### POWER PLANTS

**Problems Relating to the Development of Internal Combustion Engine Industry in India.** Proceedings of the Symposium held at The Indian Institute of Science, Bangalore, April 5–6, 1952. New Delhi, Council of Scientific & Industrial Research, 1954. 242 pp., illus., diagrs., figs.

The 34 papers presented at the symposium may be classified into three groups: (1) those relating to research and development carried out in India by the authors; (2) those reviewing recent developments abroad; and (3) those presenting proposals for future investigation and development in this country. Papers of the first category have received preference and have been printed in great detail. Papers of the other two groups have been summarized.

For information on IAS Library Service Facilities, see page 97

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

### RESEARCH

**The Application of Results of Research;** Compiled and Edited by Vera Connell in collaboration with the British Commonwealth Scientific Offices (London). New York, Academic Press Inc., 1954. 212 pp. $5.00.

How to secure the rapid translation of the results of scientific research into industrial practice has been much discussed in recent years, and the vital importance of the problem has been stressed repeatedly. This book reviews the methods adopted by the Commonwealth countries and was first presented as a Report to the British Commonwealth Scientific Conference held in Australia in 1952. The Conference considered that the material it contained was of such importance that it should be brought up to date with a view to publication.

The first part of the book reviews the various methods adopted to make the results of research widely known and more capable of immediate application, and this is followed by a critical examination of the obstacles to be overcome. A series of appendixes contain details of the organization of government research institutions throughout the Commonwealth and an account of the methods employed to encourage the utilization of the results of their research. Although the Commonwealth is the prime concern, information is given on some special methods used in the United States.

### YEARBOOKS

**Verslagen en Verhandelingen, Nationaal Luchtvaartlaboratorium** (Reports and Transactions of the National Aeronautical Research Institute); Vol. 18, 1953. Amsterdam, 1954. 261 pp., illus., diagrs., figs.

The volume is divided into three sections. In section A a survey is given of the organization of the NLL and the constitution of the Board; in a section B a description is given of the scientific work of the various sections, when possible accompanied by the number of the report in which the results are published. A list of unpublished technical reports and other miscellaneous material published during 1953 concludes this section. The third section contains a selection of reports published by the NLL, as follows:

A.1205, The field of flow through a helicopter rotor obtained from windtunnel smoke tests, J. Meyer Drees and W. P. Hendal. A.1263, Experiments on the two-dimensional flow over a NACA 0018 profile at high angles of attack, H. Wijker. F.118, Influence of compressibility on the calculated flexure-torsion flutter speed of a family of rectangular cantilever wings, J. Ijff. F.122, Application of experimental aerodynamic coefficients to flutter calculation, H. Bergh and J. Ijff. F.129, An approach to lifting surface theory, A. I. Van de Vooren. M.1857, A comparative investigation on the fatigue strength at fluctuating tension of several types of riveted lap joints, a series of bolted and some series of glued lap joints of 24 ST Alclad, A. Hartman and G. C. Duyn. S.416, Comparative fatigue tests with 24 ST Alclad riveted and bonded stiffened panels, J. H. Rondeel, R. Kruithof, and F. J. Plantema. S.421, Torsional strength and stiffness tests of wing leading edges, J. F. Besseling and W. K. G. Floor. S.426, Note on the general stress-strain relations of some ideal bodies showing the phenomena of creep and of relaxation, J. P. Benthem. V.1535, Airflow through helicopter-rotors in vertical flight, J. Meyer Drees, L. R. Lucassen, and W. P. Hendal. V.1648, The effect of the compressibility of the air on the dynamic longitudinal stability of an aeroplane in gliding flight, C. M. Kalkman and J. Buhrman.

## IAS News, *Members Elected*

(*Continued from page 94*)

**Muldoon, John D.,** B.S. Industrial Engrg., Capt., USAF; Production Analyst, Wright-Patterson AFB.

**Nephew, William A.,** B.S., Asst. Engr., Marquardt Aircraft Co.

**Niebanck, Charles F.,** B. of Ae.E., Jr. Engr., Stress Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

**Nyholm, Jack R.,** B.S. in M.E., Aero. Research Intern, Ames Aero. Lab., NACA.

**Owens, Thomas D.,** B.S. in Ae.E., Jr. Engr.—Flight Test Analysis, Chance Vought Aircraft, Inc. (Dallas).

**Raman, K. R.,** M.S.E. in Ae.E. (Aerodynamics), Test Engr., Engineering Research Institute, Univ. of Michigan.

**Ross, S. L., Jr.,** Capt., USAF; Proj. Officer—J-47 Jet Engine, Wright-Patterson AFB.

**Spiegelberg, Carl H.,** B.S. in Ae.E., Asst. Engr. "A," Northrop Aircraft, Inc. (Hawthorne).

**Steele, Ralph D.,** B.S. in Ae.E., Engr. I., Arnold Research Organization.

**Streb, Alan J.,** B.E., Assoc. Propulsion Engr., The Glenn L. Martin Co.

**Suppies, Frank T.,** B. of Ae.E., Jr. Engr., Wright Aero. Div., Curtiss-Wright Corp.

**Swift, John J.,** B.S. in Ae.E., Jr. Engr.—Aerodynamics, Douglas Aircraft Co., Inc. (Tulsa).

**Tisserand, L. E.,** B.S., Engrg. Asst. "A," Northrop Aircraft, Inc. (Hawthorne).

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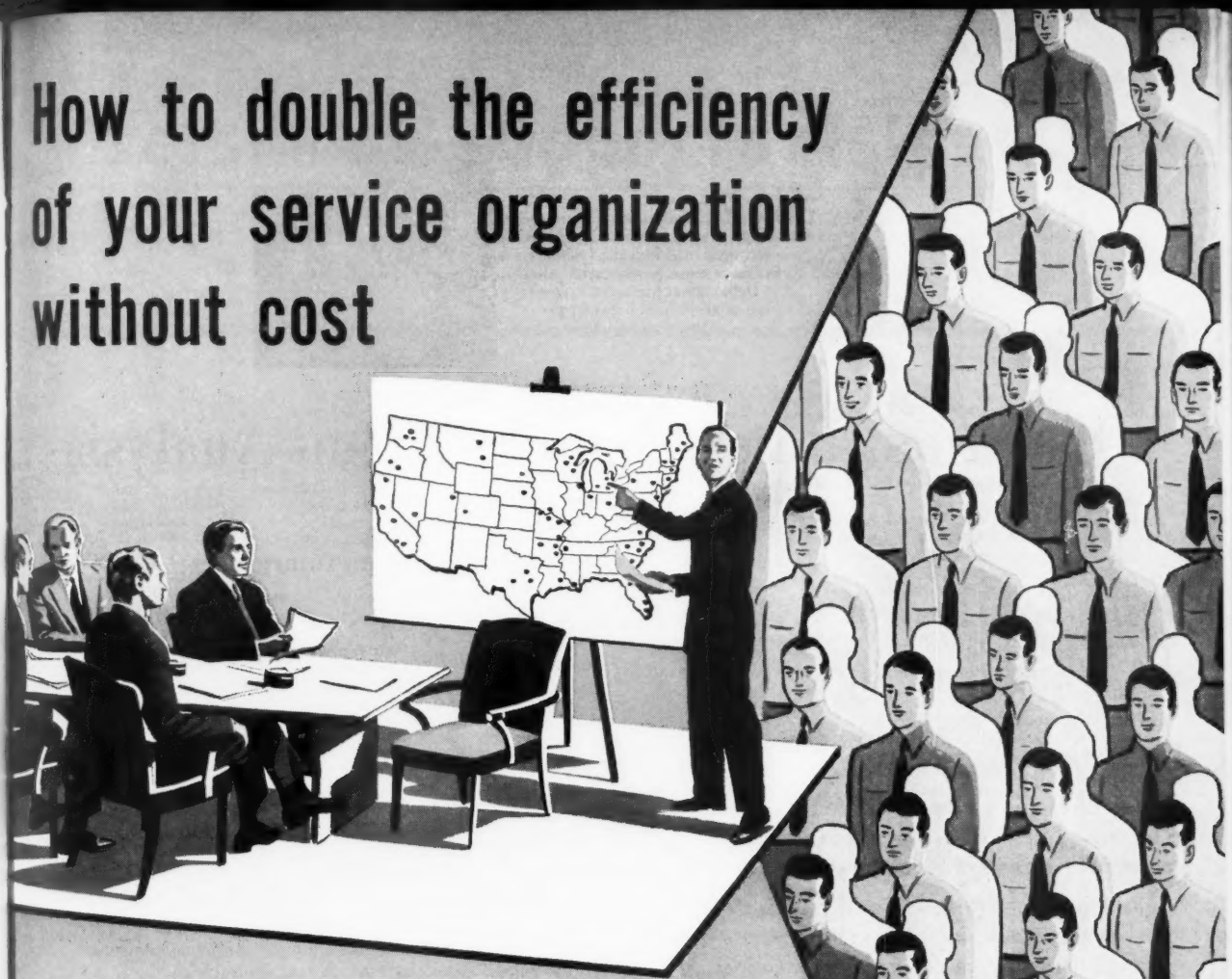

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Like all members of the Bendix Products organization, the service staff is made up of men who are specialists in the fields of fuel metering, landing gear, wheel and brake equipment. Having met and mastered service troubles for all types of planes and operating conditions, these service specialists can help immeasurably in building good will for engine builders and air frame manufacturers thru preventive maintenance that will assure lower operating costs.

Any way you look at it, for the best in research, engineering, manufacturing or *service* in the fields of fuel metering, landing gears and brakes, it pays to insist on a specialist—and the Bendix Products service organization has been a specialist in these fields for over thirty years.

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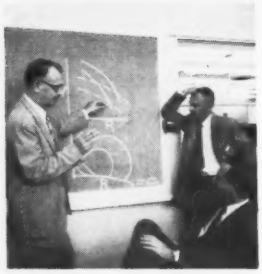
*Cerametallic brake lining, developed by Bendix Products engineers, has revolutionized all previous standards of braking efficiency. With this fundamentally different brake lining, braking capacity has been increased 50%, lining life is five times longer and delining and relining are accomplished in half the time.*

*Here is another outstanding example of Bendix creative engineering ability.*



**W. W. Lindsay, Jr.,** Electronics Committee Chairman (left), Sherwood C. Frey, Navy Studies Department Manager (seated), and R. P. Buschmann, Company Studies Department Manager (right), examine relationships between plane and radar performance.

# Operations Research and Systems Analysis

**Dr. L. Alaoglu,** Mathematics Committee Chairman (left), and Ed Quilter, Capt. U.S.N., Ret., Consultant (right), discuss alternate overseas transport routes between the U.S. and Europe.

## an important future for scientists and engineers who work in the future

**A relatively new concept** in Aeronautical Science, Operations Research at Lockheed projects creative thinking five to fifteen years in the future.

Since Operations Research was established at Lockheed in 1949, its studies and interests have covered the entire spectrum of aeronautical endeavor, forecasting and evaluating future research and development trends.

The growing importance of Lockheed Operations Research has created openings in a wide range of fields, including the following occupations:

1. **Meteorologists, Climatologists or Specialists in Oceanography**
   with degrees in Meteorology or allied subjects; at least five years' experience; and potential additional capability in some other field such as Mechanical or Electrical Engineering.

2. **Electronics Engineers**
   with a Master's Degree in Electronics or Physics and at least five years' experience, including micro-waves or communications.

3. **Missile Fire Control and Guidance Engineers**
   preferably with a Master's Degree and at least three years' experience in fire control systems.

4. **Nuclear Weapons and Effects Scientists**
   with a Ph.D. in Physics or Mathematics and at least three years' experience in current and future nuclear weapons packaging practices, yields and effects.

5. **Aeronautical Engineers**
   with a Master's Degree in Aeronautical Engineering; at least ten years' experience in engineering departments such as structures, preliminary design and aerodynamics; and ability to create, design and evaluate spectra of complete aircraft systems of the future.

6. **Guided Missiles Aeronautical Engineers**
   with a Bachelor's Degree in Aeronautical Engineering and at least three years' experience in aerodynamics and design of missiles.

7. **Economists**
   with a B.A. Degree and experience in cost accounting or bookkeeping; experience in aircraft and missile systems costing desirable.

8. **Physicists and Mathematicians**
   with a degree and inclination toward operations research and systems analysis. Ability to apply probability theories and advanced mathematical techniques desirable.

9. **Operations Researchers or Systems Analysts**
   with degrees or training in Operations Research.

10. **Air Force Operational Experience**
    The position requires an Aeronautical Engineering Degree; experience as a senior pilot with fighter, logistics or cargo experience; and experience at staff or headquarters level in the Air Force.

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# Personnel Opportunities

**This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.**

## Wanted

**Aerodynamic Research Personnel**—The analytic aerodynamics division of Sandia Corporation, a subsidiary of the Western Electric Company and prime contractor to the Atomic Energy Commission, needs two aerodynamicists. Applicants with advanced degree(s) and some experience are preferred. Our Research and Development Program requires people with general knowledge of transonic and supersonic flow stability, instrumentation, pressure measurement, and testing problems. Tasks are assigned on a project engineer basis, and direct responsibility is placed on the individual. Excellent employee benefits and research facilities. Address inquiries to the Professional Employment and Personnel Division (GE-19), Sandia Corporation, Sandia Base, Albuquerque, N. M.

**Aeronautical Power-plant Research Engineer**—GS-12, $7,040 per annum, to investigate various propulsion systems, both liquid and solid propellant types for new guided missiles. **Aerodynamicist**—GS-9, $5,060 per annum, to assist in establishing aerodynamic characteristics of guided missiles in the preliminary design stage. Write or send application on Standard Form 57, which can be obtained at your Post Office, to Commanding General, Redstone Arsenal, Huntsville, Ala., Attention: C. N. Duggan, Civilian Personnel Division.

**Engineers**—AiResearch Manufacturing Company—Positions are available at Los Angeles and Phoenix in the following fields for qualified engineers interested in working on advanced problems associated with the accessory equipment demands of high-speed, high-altitude flight. Positions available offer excellent remuneration and challenging professional environment for engineers of advanced education or experience. **Aerodynamics**—Design of turbomachinery components. Requires inventive concept of aerodynamic elements and supervision of complete aerodynamic design and testing. **Electrical**—No electronics required. Products are largely electromechanical. Good opportunity for theoretical research as well as design of unusual and advanced heat-transfer apparatus. **Instrumentation**—A specialist in electronic instrumentation and a specialist in mechanical and pneumatic instruments are required. Work is concerned with design and advisory service for one of the world's largest and most complete aircraft accessory and equipment environmental and performance testing facilities. **Pneumatic Controls**—Analysis of transient and steady-state performance of aircraft valves, regulators, and complete control systems. **Stress and Vibration**—An opportunity to work in an advanced stress group concerned with theoretical and empirical analysis of some of the most complex stress and vibration problems associated with rotating turbomachinery. Upon completion of a projected new laboratory, basic material research will be available.

**Engineers**—Cessna Aircraft Company, the world's largest producer of light commercial aircraft, has immediate openings for Aircraft Design Engineers with 2 to 5 years' experience in the following fields: air-frame structural layout; equipment installation; hydraulic systems; power-plant installations. For confidential evaluation send résumé to: Employment Manager, Department AER, Cessna Aircraft Company, Wichita, Kan.

**The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.**

**Engineers—Aeronautical Research Development and Design Engineer**—GS-13, starting salary $8,360 per annum. Serves as an engineering specialist in aircraft structures for the Office of the Inspector General, USAF. Background and experience should qualify applicant in the structural design of aircraft, static and repeat load testing, and knowledge of the various aircraft systems and of the interpretation and evaluation of fractures of aircraft structural materials. Position also entails participation in investigations of selected USAF aircraft accidents in the field wherein the circumstances indicate that the aircraft systems or structure may be a cause factor for the accident. **Aeronautical Research Development and Design Engineer**—GS-13, starting salary $8,360 per annum. Serves as an engineering specialist in jet power-plant engineering and installation for the Office of the Inspector General, USAF. Background and experience should qualify applicant in the theory, design, and installation of jet power plants. In addition, a knowledge of reciprocating engines and propellers is desirable but not mandatory. Position also entails participation in investigation of selected USAF aircraft accidents in the field wherein the circumstances indicate that some aspects of the power plant may be a cause factor for the accident. **Aerodynamic Development Engineer**—GS-14, starting salary $9,600 per annum. Serves as the engineering specialist in the aerodynamic field for the Office of the Inspector General, USAF. Background and experience should qualify applicant for sonic, transonic, and supersonic aerodynamics deviation of basic air loads, stability, controllability, and maneuverability phenomena and problems in relation to design of aircraft, aircraft performance testing, and evaluation and reduction to standard conditions. Position also entails participation in investigations of selected USAF aircraft accidents in the field wherein the circumstances concerning the flight path and behavior of the aircraft prior to the crash indicate that one of the facets of aerodynamics may be a cause factor for the accident. Send replies to: Headquarters, San Bernardino Air Materiel Area, Norton Air Force Base, San Bernardino, Calif.

**Engineers—Aircraft Performance Engineer**—GS-11, $5,940 per annum; GS-9, $5,060 per annum; GS-7, $4,205 per annum. Duty post: Washington, D.C. Makes detailed engineering studies and calculations pertaining to the analysis of performance characteristics of Naval aircraft including helicopters, guided missiles, and target drones. **Aircraft Structural Loads Engineer**—GS-12, $7,040 per annum; GS-11, $5,940 per annum. Duty post: Washington, D.C. Plans, initiates, and administers research and development projects in structural loads (flights, ground, and water loads). Examination and acceptance of contractors' reports regarding structural ground loads. Investigation of special problems. **Aircraft Development Engineer (Hydrodynamics)**—GS-13, $8,360 per annum; GS-12, $7,040 per annum; GS-11, $5,940 per annum. Duty post: Washington, D.C. Initiates and directs hydrodynamic research and development projects. Analyzes hydro characteristics and approves hydro specifications of all seaplane designs for procurement. **Aircraft Stability and Control Engineer**—GS-12, $7,040 per annum; GS-11, $5,940 per annum; GS-9, $5,060 per annum. Duty post: Washington, D.C. Investigates and analyzes aerodynamic characteristics of Naval aircraft from results of wind-tunnel investigations. **Turret Design Engineer**—GS-12, $7,040 per annum; GS-11, $5,940 per annum. Duty post: Washington, D.C. Responsible for technical and administrative supervision of research and development contracts for aircraft turret systems and/or turret components. **Aircraft Flutter and Vibration Engineer**—GS-12, $7,040 per annum; GS-11, $5,940 per annum. Duty post: Washington, D.C. Responsible for research and development (for aircraft, guided missiles, and target drones) in the fields of vibration, flutter, and structural dynamics and for the preparation of all specifications in these fields. **Aircraft Preliminary Design Engineer**—GS-11, $5,940 per annum. Duty post: Washington, D.C. Preliminary design studies of new types of guided missiles; engineering analyses leading to complete missile performance characteristics involving speed, rate of climb, maneuverability, etc. **Aircraft Structural Development Engineer (Weight and Balance)**—GS-12, $7,040 per annum. Duty post: Washington, D.C. Weight control engineering for experimental and production aircraft of all types through all stages of design, production, service use, and modification. **Aeronautical Power Plant Research Engineer**—GS-13, $8,360 per annum. Duty post: Washington, D.C. Planning, organizing, and initiation of specific aircraft power-plant designs and general design studies of all types of aircraft and guided-missile power plants. Applications may be submitted on Standard Form 57, Application for Federal Employment to Department of the Navy, Bureau of Aeronautics, Washington 25, D.C.

**Engineers, Electronic Scientists, Metallurgists, Physicists, Psychologists, Physiologists, Technologists**—The Naval Air Material Center located in the U.S. Naval Base, Philadelphia, has vacancies in the above positions for qualified personnel. The vacancies are at Grade GS-5, $3,410 per annum, to GS-13, $8,360 per annum. Engineers are especially needed for work in connection with catapults, launchers, arresting gear, and their components, involving four main categories as follows: Basic design for the above equipment; test and development work at shore stations and on board U.S. Navy ships; evaluation of new equipment and establishment of performance parameters; and applied research on the many problems relevant to this field. Interested persons are urged to submit applications to the Industrial Relations Department, Naval Air Material Center, Naval Base, Philadelphia 12, Pa. Standard Form 57, Application for Federal Employment, may be obtained from the above address or at any first- or second-class Post Office.

## RESEARCH AERONAUTICAL ENGINEERS

The Aero-Mechanics Department of the Cornell Aeronautical Laboratory has positions available for people with B.S. degrees and with experience in:

### APPLIED AERODYNAMICS AND STRUCTURES

Opportunities in preliminary design of aircraft and missile systems. Work will involve technical evaluation and authorship of reports. Originality is expected and fostered.

### PROPULSION SYSTEMS

Opportunity with regard to technical evaluation and detail analysis of advanced aircraft and missile propulsion systems. A background in thermodynamics with some mechanical design experience desirable.

**CORNELL AERONAUTICAL LABORATORY, INC.**
Buffalo 21, New York

## ENGINEERS

The APPLIED PHYSICS LABORATORY OF THE JOHNS HOPKINS UNIVERSITY offers an exceptional opportunity for professional advancement in a well-established laboratory with a reputation for the encouragement of individual responsibility and self-direction. Our program of

**GUIDED MISSILE RESEARCH AND DEVELOPMENT**

provides such an opportunity for men qualified in:

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**RAMJET DESIGN AND ANALYSIS**
**MISSILE SYSTEMS DEVELOPMENT**
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*Please send your résumé to*

Glover B. Mayfield
**APPLIED PHYSICS LABORATORY**
**THE JOHNS HOPKINS UNIVERSITY**
8621 Georgia Avenue
Silver Spring, Maryland

## Attention

## ENGINEERS

Aeronca Manufacturing Corporation, a leading sub-contractor for the aircraft industry has immediate openings in its new research and development group for engineers qualified in

**Applied Aerodynamics**
**Flight Control Systems**
**Aircraft Structures**
**Propulsion Systems**
**Electronics**

Build your career with an expanding progressive company where advancement is assured for engineers with ability and initiative. If you have three or more years' experience, a basic or advanced engineering degree, and are capable of original development activity in aircraft and missile systems, you are invited to contact our Personnel Office at 1712 Germantown Road, Middletown, Ohio.

## RESPONSIBLE POSITIONS FOR ENGINEERS, PHYSICISTS, MATHEMATICIANS

### WEAPON SYSTEM ANALYSIS AND WEAPON SYSTEM PLANNING OF GUIDED MISSILE PROJECT

Openings exist for qualified personnel with two to ten years' experience in Aeronautics, Electronics, Applied Mathematics, Technical Economics or Physics. Fields of work include:

**OPERATIONS RESEARCH**
**WEAPON EFFECTS**
**TECHNICAL ECONOMICS**
**LONG RANGE PLANNING**
**INVESTIGATION OF NEW WEAPON CONCEPTS**

Degrees desired are the Bachelor's or Master's degree in Aeronautical or Electronic Engineering, Ph.D. in Mathematics or Physics or the Master's degree in Business Administration or Economics when coupled with an engineering B.S. Please forward personal resume to:

**MISSILE & CONTROL EQUIPMENT DEPT. B**
Engineering Personnel
**NORTH AMERICAN AVIATION, INC.**
Downey, California

## Are You One of Three Men

**we are seeking to fill these important openings? All are in the field of**

**VIBRATION and MECHANICAL METALLURGY**
These positions require men with a degree in either mechanical, metallurgical, aeronautical or electrical engineering, theoretical and applied mechanics, or physics. In addition—

**ONE POSITION REQUIRES . . .**
A man with formal education in vibration analysis with emphasis on theoretical approach.

**THE SECOND POSITION REQUIRES . . .**
A man with practical experience in solving vibration problems either on rotating machinery or aircraft equipment.

**THE THIRD POSITION REQUIRES . . .**
Some knowledge of the study of fatigue of metals and fatigue testing techniques. Also familiarity with methods of experimental stress analysis.

We are rapidly expanding our established line of

**JET AIRCRAFT EQUIPMENT**
including such items as starters, fuel controls, hydraulic pumps, cockpit cooling units, etc., in addition to our new

**TURBINE ENGINE PROPELLERS**

These positions offer excellent salary and job security as well as fine chance for advancement as our program grows. Our new plant is ideally located midway between Hartford, Conn., and Springfield, Mass. We help you to locate a home in either urban or rural areas and to pay moving expenses.

*All replies held in strict confidence. Please send a complete resume of your experience including salary requirements to Mr. A. J. Fehlber at*

**HAMILTON STANDARD**
Division of
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## Aeronautical or Mechanical Engineers

*For development of*

**GUIDED MISSILES AND ROCKETS**

Applicants must have obtained their Masters', Professional, or Doctors' Degree since 1945 and be between 20 and 35 years of age. Work involves theory and application in such fields as:

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- **Fluid Dynamics**
- **Structural and Mechanical Design**
- **Heat Transfer and Thermodynamics**
- **Systems Analysis**

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**Jet Propulsion Laboratory**
4800 Oak Grove Drive
Pasadena 3, California

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# ENGINEERS

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Our advanced engineering program and established position in the aircraft industry offer the qualified engineer exceptional professional opportunity.

Submit confidential inquiries to Professional Employment Office.

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**SUPERSONIC**
# TIGER

Grumman, one of the most stable aircraft companies in the industry, needs engineers to work on the supersonic Tiger and new Cougar II. With Grumman, your home will be Long Island, the playground of New York. If you are an experienced aircraft engineer, or a recent engineering graduate, send your resume to Engineering Personnel Dept. Interviews at Employment Office.

**NEEDED NOW:**
*Wing and Fuselage Designers*
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# AEROTHERMODYNAMIC ENGINEERS FOR LONG RANGE GUIDED MISSILE PROGRAM

Development of ramjet and turbojet air induction systems. Investigation and study of boundary layer phenomenon and control; improvement of flow profiles after shock interaction and diffusion; design and development of high pressure recovery diffusers.

North American facilities include supersonic wind tunnels. Construction will soon begin on a new 7 x 7 foot tri-sonic wind tunnel. Company engineers also conduct research and development at government facilities throughout the country.

For additional information, please forward resume to:

Missile & Control Equipment Dept.,
Engineering Personnel

**NORTH AMERICAN AVIATION INC.**
12214 Lakewood Blvd.
Downey, California

## Guided Missiles Engineers

# An Important Message from the

# GUIDED MISSILES DIVISION

## of REPUBLIC AVIATION

The opening of a brand-new plant at Hicksville, Long Island, with extensive guided missiles facilities and laboratories creates new opportunities in Republic's Guided Missiles Division for men of unique abilities who can meet the demands of advanced work in the field.

This would be an opportune time to join our staff at Hicksville (only 45 minutes from mid-town New York), as we move toward new and unsolved challenges.

And . . . you will be interested to know that Republic's high salaries and free employee-family benefits are considered exemplary in industry.

***Immediate Openings for:***

**DESIGN ENGINEERS**—Engineering degree or equivalent, 7 to 10 years' experience. Thorough knowledge of aircraft structural-mechanical problems, aircraft or guided missile production and prototype fabrication techniques; ability to design mechanical devices and structures as related to aircraft or guided missiles; familiarity with fundamentals of structural theory and practice; ability to handle design project with minimum supervision and supervise small group of designer and draftsmen, from design concept to delivery to customer.

**PRINCIPAL AERODYNAMICIST**—Preliminary Design B.S., M.S. or Ph.D. in Aeronautical Engineering. 6–10 years of aerodynamic design experience during which both theoretical and practical aspects of subsonic and supersonic aerodynamics have been applied to preliminary design and analysis of high speed guided missiles and/or aircraft. Applicant must be thoroughly familiar with performance and control parameters. Will work closer with electronic, servo, and systems engineers to produce most efficient and reliable weapons systems.

**SYSTEMS ENGINEERS**—M.S. or Ph.D. in Engineering or Applied Mathematics with 5 years' experience on one or more of following: missile guidance and control, servo-mechanisms analysis, noise and information theory, Analogue Computers, aircraft stability and control. Work on non-conventional control problems. Possess analytical mind and originality.

**TECHNICAL WRITER**—Engineering degree or B.A. with engineering background. 5 years' combined experience in preparation of aircraft and/or guided missile technical reports. Interpret technical information resulting from analysis and study from all sections of Guided Missiles Engineering and editing same, integrating into final technical reports.

**PRINCIPAL STRESS ANALYST**—Engineering degree with 7 years' aircraft or guided missile stress analysis experience. Thorough knowledge of structural theory and practice; aircraft or guided missile loads; analyze complex structures by energy or similar methods; working knowledge shop practice; able to run stress work of small project with minimum supervision and supervise group of stress analysts.

**WEAPONS SYSTEMS PROPOSAL ENGINEER**—Work closely with technical groups to study and develop ideas into proposals for sales purposes, and in cases of proposal request from a potential customer, make certain that proposal specifications and requirements are maintained. Assist in planning and estimating costs and man-hours; and presenting proposals to potential customer. Missile systems and/or aerodynamic background required.

*Please forward complete resume to attention of Mr. R. Reissig*

**GUIDED MISSILES DIVISION**
**REPUBLIC AVIATION CORPORATION**

*447 Broadway*
*Hicksville, Long Island*
*New York*


**Engineers—General Engineer (Electronics)**—GS-13, $8,360 per annum. Chief of Instrumentation Section—Supervises the development and application of electronics equipment and instrumentation for data recording of high-speed test vehicles and parachute characteristics. Supervises the assembly, maintenance, and instrumentation of all parachute test vehicles including rocket boosted units. Serves as adviser to the Naval Parachute Unit and the USAF Parachute Test Group on all questions regarding electronics equipment and specialized instrumentation. Experience with telemetering, tape recording, high-frequency electronics, and data-recording systems necessary. M.S. or D.S. in electronics required. **General Engineer (Aerodynamics)**—GS-13, $8,360 per annum. Chief of Development Section—Supervises the planning, testing, and evaluation of all projects concerning guided-missile recovering, specialized equipment recovery, and all parachute research projects. Responsible for the design and development of specialized vehicles and test equipment. Supervises the aerodynamics and ballistics and the data-evaluation group. Experience in aerodynamics preliminary design and flight-test engineering desirable. M.S. or B.S. in aeronautics required. Three **Aeronautical or Mechanical Engineers**—GS-9 to GS-11, $5,060 to $5,940 per annum. For development work in missile recovering, high-speed parachute recovery of ordnance and air-borne equipment, and high-speed aircraft escape and for aerodynamics and ballistics calculation and data evaluation of high-speed test vehicles and general parachute recovery work. **Engineering Draftsman or Designer**—GS-7; to work on design of specialized recovery equipment, aircraft installations, and modification of air-borne equipment. Must be able to work independently from sketches. Experience in general aeronautical design required. Submit applications to Commander, 6511th Test Group (Parachute), NAAS, El Centro, Calif.

**Professor of Airplane Design**—The Division of Aeronautical Engineering, Instituto Technologico de Aeronautica, located near São Paulo, Brazil, has a position open for an Aircraft Design Engineer to be Professor and Head of the Airplane Design Department. Applicant should have Masters Degree in Aeronautical Engineering and 16 years' experience in industry, research, or teaching aircraft design. Knowledge of Portuguese not essential. Please address inquiry, enclosing information on degrees and experience, to: Professor Andre J. Meyer, Rector, Instituto Technologico de Aeronautica, Sao José dos Campos, São Paulo, Brazil.

**Professors**—The USAF Institute of Technology, Wright-Patterson Air Force Base, Ohio, has vacancies in the Department of Mathematics. Most of the work is at advanced undergraduate and graduate level. Employment will be effected in accordance with Civil Service regulations. Grade levels available are: GS-9 ($5,060), instructor; GS-11 ($5,940), assistant professor; and GS-12 ($7,040), associate professor. Applications should be made on Standard Form 57, available at any Post Office, or by letter to Head of the Department of Mathematics, Resident College, USAF Institute of Technology, Wright-Patterson Air Force Base, Ohio.

**634. Tool Engineer**—To work closely with Manager of Engineering on design of dies, patterns, jigs, and fixtures and development of outside sources. Must have at least 5 years' aerodynamic experience with turbine blades and vanes. Permanent position with progressive, expanding firm. Include in your résumé full details, experience, education, and personal history. Reply will be treated in strict confidence.

## Available

**641. Engineer**—B.S.Ae.E., 1948. Total engineering experience over 7½ years, of which 6½ years are full time. Two and one-half years' experience on high-pressure aircraft hydraulic sys-

tems and missile component design. Two years as design engineer on small electromechanical components, and two years as development engineer on component packaging of missile automatic flight controls. Background includes multiengined commercial pilot's license, military flying experience, and aircraft maintenance officer USAF Reserve. Desires position of greater responsibility in technical or administrative field. Location preferred—South, West, or Texas. Résumé will be sent upon request showing position(s) available.

**639. Research Pilot**—B.S.I.A.; age 34. Commercial Certificate, MEL, SEL, currently acquiring CAA Instructor's rating. Have held USAF Instructor's ratings since 1944. Air experience in Europe, United States, and Alaska, predominately MEL with concurrent work in meteorology. Professional member, American Meteorology Society and former practicing forecaster. Some aircraft manufacturing background including engine test, patent, administrative, and supervisory experience. Desires position emphasizing MEL piloting and meteorology. Salary and location secondary.

**638. Technical Administrative Engineer**—B.S.M.E.; age 41. Sixteen years in aircraft engineering including 2 in mechanical laboratory, 10 in structural test, and 4 in missile structural and mechanical development at increasingly responsible levels. Experienced organizer, able to get top results in design, development, and testing of mechanical and electromechanical systems and structure. Desires responsible position with a challenge. Present salary $12,000. Personal résumé on request.

**636. Mechanical Engineer**—With integrated background in product design, development, research, and technical management. Fields cover light to heavy industrial equipment, ordnance, and plant engineering. Particular interest in building personnel. Advanced degree. Registered. Desires lead (or assistant) position in smaller firm or equivalent.

**635. Research and Development Engineer**—B. S., M.S., D.Sc.; age 39. Eight years' experience as Professor of Aeronautical Engineering and Instructor of Engineering Physics; 7 years' experience as division head, aircraft and missile dynamics and aerodynamics research and development, and as consultant on all phases of industrial and Government defense projects. Has had supervisory responsibility for theoretical and experimental research in aeroelasticity, heat transfer, acoustics, aerodynamics, hydrodynamics, propulsion, and other allied engineering subjects. Desires responsible position with industrial concern or educational institution in East Coast area.

**633. Aero and Hydrodynamicist**—Dr. of Engineering with 22 years of experience in aerodynamic research, wind-tunnel flight and hydrodynamic testing, and design and development primarily in the field of aeronautics. Author of technical reports, published papers, and one book. Is interested either in teaching and research position or in applied research and development work, in or out of New York City area. Please write for particulars.

**631. Executive Assistant—Administrative Engineer**—age 30, Bachelor of Aeronautical Engineering. Some graduate work in Industrial Engineering, Management. Completed USAF course in Technical Management. Three years' experience includes sales, sales promoting, and methods improvement. One year's experience as photo-reconnaissance project engineer for the Air Force. Handled development of navigation equipment. Three years' experience as chief weapons systems officer for the Air Force for bombardment-type aircraft (present position). Work includes aircraft development and control to maintain its qualitative efficiency, contractor-Government liaison, contract administration, etc. Desires challenging management position. Prefers Eastern relocation. Résumé furnished upon request.


# MESSAGE TO AN ENGINEER THINKING ABOUT THE FUTURE— HIS FUTURE

**Take a few moments now to review the progress of your career. Does your present position offer you a future that fully utilizes your creative abilities?**

**Compare your present assignment with the diversified, stimulating pursuits that increase the inventive challenge of Fairchild's team of qualified engineers. These men are working on engineering advances for the famous C-119 Flying Boxcar and the soon-to-be-produced C-123 Assault Transport. More than that, they are developing tomorrow's jet fighters . . . special reconnaisance aircraft . . . jet bombers and transports. The men at Fairchild know that *planned* project diversification keeps them in the forefront of the field of aerodynamics.**

**Gracious country living only minutes away from urban Baltimore or Washington . . . paid pension plan . . . an excellent salary with paid vacations . . . ideal working environment . . . generous health, hospitalization and life insurance . . . and the many other benefits of a progressive company add to the pleasure of working with Fairchild.**

**You'll be investing wisely in a secure future if you take time today to write to Walter Tydon, Chief Engineer, outlining your qualifications. Your correspondence will be kept in strict confidence, of course.**

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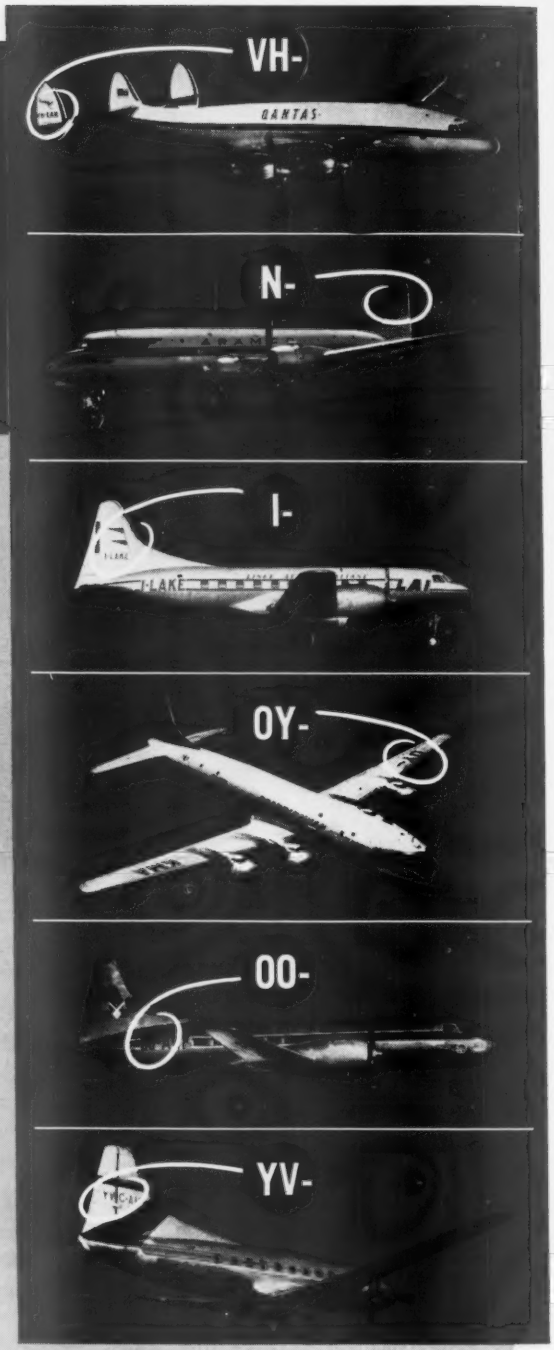


## AIRCRAFT NATIONALITY MARKS

| | |
|---|---|
| Afghanistan | YA |
| *Argentina | LV |
| *Australia | VH |
| Austria | OE |
| *Belgium | OO |
| * Belgian Congo | OO |
| *Bolivia | CP |
| *Brazil | PP, PT |
| *Burma | XY, XZ |
| *Canada | CF |
| *Ceylon | CY |
| *Chile | CC |
| *China (Taipeh Taiwan) | XT |
| *Colombia | HK |
| *Cuba | CU |
| Czechoslovakia | OK |
| *Denmark | OY |
| *Dominican Republic | HI |
| *Ecuador | HC |
| Egypt | SU |
| El Salvador | YS |
| *Ethiopia | ET |
| *Finland | OH |
| *France | F |
| *Greece | SX |
| Guatemala | TG |
| Haiti | HH |
| *Iceland | TF |
| *India | VT |
| *Indonesia | PK |
| Iran | EP |
| Iraq | YI |
| Ireland | EI, EJ |
| *Israel | 4X |
| *Italy | I |
| *Japan | JA |
| Jordan | TJ |
| Lebanon | OD |
| Liberia | EL |
| Luxembourg | LX |
| *Mexico | XA, XB, XC |
| *Netherlands | PH |
| * Netherlands Antilles | PJ |
| * Netherlands Surinam | PZ |
| * Netherlands New Guinea | JZ |
| *New Zealand | ZK, ZL, ZM |
| *Nicaragua | AN |
| *Norway | LN |
| *Pakistan | AP |
| Panama | HP |
| *Paraguay | ZP |
| *Peru | OB |
| *Philippine Republic | PI |
| Poland | SP |
| *Portugal | CS, CR |
| *Saudi Arabia | HZ |
| *Spain | EC |
| *Sweden | SE |
| *Switzerland | HB |
| Syria | YK |
| *Thailand | HS |
| *Turkey | TC |
| *Union of South Africa | ZS, ZT, ZU |
| *United Kingdom | G |
| Colonies and Protectorates | VP, VQ, VR |
| *United States | N |
| *Uruguay | CX |
| *Venezuela | YV |

## *VICKERS AIRCRAFT HYDRAULICS IN USE

**This table includes all nationality marks that have been formally notified to ICAO up to June 19, 1953. Seventy-five percent of the countries . . . those marked with an asterisk . . . have registered commercial aircraft which use Vickers Hydraulics. Vickers Hydraulic Equipment for aircraft is so widely preferred because it is dependable, efficient, light weight and compact. Ask for new Bulletin A-5200-B.**

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***ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921***

# Index to the

# Aeronautical Engineering Review, Volume 13

## January–December, 1954


| | Month | Page |
|---|---|---|
| **Aerodynamics—** | | |
| Application of Sailplane Performance Analysis to Airplanes, August Raspet | *Aug.* | 56 |
| Design of an Airfoil Oscillator, Robert Maurice Williams | *Oct.* | 80 |
| Flight Measurements of Trailing-Edge Suction on a Sailplane, August Raspet and Glenn D. Bryant | *Jan.* | 26 |
| Flight Observations of Suction-Stabilized Boundary Layers, B. H. Carmichael | *Feb.* | 36 |
| Laminarization Through Boundary-Layer Control, G. V. Lachmann | *Aug.* | 37 |
| **Air Transport—** | | |
| Design of the Transport Helicopter, David E. Postle | *Mar.* | 70 |
| Economic Considerations of the Transport Helicopter, James B. Edwards | *Apr.* | 76 |
| Evolution of the Boeing Jet Tanker-Transport Design, Maynard L. Pennell | *Aug.* | 32 |
| Human Factors in Jet-Transport Design, Frank C. Hale | *Oct.* | 84 |
| Operational Economics of Scheduled Helicopter Transportation, Robert L. Cummings, Jr. | *June* | 66 |
| Turboprop Engines for Tomorrow's Transport, E. F. Heaton, C. S. Constantino, and W. H. Ziegler | *Mar.* | 52 |
| **Aviation Medicine—** | | |
| Designing the Cockpit for High-Speed Flight, S. N. Roscoe | *Dec.* | 47 |
| Human Factors in Jet-Transport Design, Frank C. Hale | *Oct.* | 84 |
| Man and Machine Between Atmosphere and Space, Heinz Haber | *Nov.* | 56 |
| BAILEY, ROBERT A. Application of Operations-Research Techniques to Air-Borne Weapon System Planning | *Oct.* | 72 |
| BAKER, F. A., AND F. G. TIMMEL. Magamps Applied to Aircraft Control Problems | *Nov.* | 46 |
| BLANTON, H. ELMORE. Use of Flight Simulators in the Design of Aircraft Control Systems | *Feb.* | 29 |
| BONNEY, FRED S. The Operational Application of Automatic Pilots | *July* | 47 |
| BOSTON, JOHN P., JEROME M. SCHWARZBACH, AND JOSEPH E. JENKINS. A Method of Locating the Airplane Take-Off Point and Determining the Take-Off Speed | *July* | 42 |
| BREWER, GIVEN. Calibrating the PBY-6A Airplane for Meteorological Purposes | *Feb.* | 24 |
| BROWN, L. D. Integrated Electric Control for the General Electric J47-17 Jet Engine | *May* | 59 |
| BRYANT, GLENN D., AND AUGUST RASPET. Flight Measurements of Trailing-Edge Suction on a Sailplane | *Jan.* | 26 |
| CARMICHAEL, B. H. Flight Observations of Suction-Stabilized Boundary Layers | *Feb.* | 36 |
| CARMODY, EDMUND O. The Role to Be Played by Training Devices in the Training of Aviation Personnel | *May* | 74 |
| CHRISTENSON, CARL M. Management's Economic Interest in Safety | *Aug.* | 52 |
| CHRISTOFFERSON, F. E. The Flight-Test Organization | *June* | 62 |
| CONSTANTINO, C. S., E. F. HEATON, AND W. H. ZIEGLER, Turboprop Engines for Tomorrow's Transport | *Mar.* | 62 |
| CORNWALL, E. W. Thermal Considerations in Electrical Accessory Design | *Dec.* | 59 |
| CUMMINGS, ROBERT L., JR. Operational Economics of Scheduled Helicopter Transportation | *June* | 66 |
| DAWSON, L. G. The Best Use of the Energy from a Turbine Engine for Aircraft Propulsion | *June* | 48 |
| **Design—** | | |
| An Air-Powered Servo-Actuator, Ralph Kress | *Jan.* | 52 |
| Airplane Design in Relation to Safety, R. W. Rummel | *Apr.* | 70 |
| Designing the Cockpit for High-Speed Flight, S. N. Roscoe | *Dec.* | 47 |
| General Design Aspects of Flight Refueling, Walter P. Maiersperger | *Mar.* | 52 |
| Optimization of Airplane and Engine Performance, E. F. Pierce | *June* | 52 |
| Optimization of Power-Plant and Airplane Performance—A Symposium | *June* | 42 |
| Porous Metals in Aircraft, David B. Pall | *July* | 36 |
| Practical Considerations in the Optimization of Airplane and Engine Performance, E. H. Heinemann | *June* | 44 |
| The Self-Contained Airplane, Donald R. Elliott | *Sept.* | 83 |
| Suggested Supersonic Design Considerations, R. J. Woods | *June* | 46 |
| The Use of Closed-Curve Equations of Variable Degree in Airplane Fuselage Lofting, Jackson W. Granholm | *July* | 52 |
| The Use of an Operational Flight Trainer as a Research Tool for Aircraft Instrumentation and Cockpit Rearrangement, Joseph N. Pecoraro | *May* | 86 |
| Wing Design for Practical High-Speed Aircraft, Donald W. Finlay | *Dec.* | 44 |
| DOUGLAS, DONALD W. Our Shrinking Globe (*Editorial*) | *Aug.* | 30 |
| DOUGLAS, L. L. Development Problems of the Large Helicopter | *Apr.* | 60 |
| DRYDEN, HUGH L. Aeronautical Research and the Art of Airplane Design (*Editorial*) | *Dec.* | 40 |

| | Month | Page |
|---|---|---|
| **Editorial—** | | |
| An Added Service | *Sept.* | 40 |
| Aeronautical Research and the Art of Airplane Design, Hugh L. Dryden | *Dec.* | 40 |
| AGARD—An important NATO organization comes of age | *July* | 24 |
| Changeover | *Jan.* | 24 |
| Customer Appraisal | *Nov.* | 40 |
| Excerpts from the Seventeenth Wright Brothers Lecture, Glenn L. Martin | *Feb.* | 22 |
| Honors Night Dinner Address, Charles A. Lindbergh | *Mar.* | 48 |
| Northern Neighbor | *June* | 40 |
| Our Chief Stock-in-Trade | *Apr.* | 38 |
| Our Shrinking Globe, Donald W. Douglas | *Aug.* | 30 |
| The Systems Concept | *May* | 54 |
| Up and Down and Round and Round, Leonard S. Hobbs | *Oct.* | 38 |
| EDWARDS, JAMES B. Economic Considerations of the Transport Helicopter | *Apr.* | 76 |
| **Electronics & Electrical Equipment—** | | |
| The Basis for Compromise Between Theoretical Performance and Operational Reliability, William D. McGuigan | *Dec.* | 65 |
| Cooling Supersonic Electronic Equipment, Doyle C. Wells | *May* | 70 |
| Integrated Electric Control for the General Electric J47-17 Jet Engine, L. D. Brown | *May* | 59 |
| Liquid Cold-Plate Method for Cooling of Air-Borne Electronic Equipment, Marshall P. Sandelin | *May* | 82 |
| Magamps Applied to Aircraft Control Problems, F. A. Baker and F. G. Timmel | *Nov.* | 46 |
| Operational Telemetering—An Aid to Air Navigation, M. V. Kiebert, Jr. | *May* | 94 |
| Practical Expectations and Limitations of the Reliability Problem, Russell H. Lindsay | *Oct.* | 65 |
| Some Recent Developments in Aviation Electronics, Welman A. Shrader | *May* | 56 |
| Thermal Considerations in Electrical Accessory Design, E. W. Cornwall | *Dec.* | 59 |
| ELLIOTT, DONALD R. The Self-Contained Airplane | *Sept.* | 83 |
| FINLAY, DONALD W. Wing Design for Practical High-Speed Aircraft | *Dec.* | 44 |
| **Flight Propulsion—** | | |
| The Best Use of the Energy from a Turbine Engine for Aircraft Propulsion, L. G. Dawson | *June* | 48 |
| Compressor Bleed in Turbine-Powered Aircraft, B. L. Messinger and W. W. Merrill, Jr. | *Sept.* | 50 |
| Effect of Aircraft Jet-Engine Exhaust Impinging on Airfield Surfaces, N. L. Fox and S. J. Harvey | *July* | 26 |
| Integrated Electric Control for the General Electric J47-17 Jet Engine, L. D. Brown | *May* | 59 |
| Method for Measuring Thrust in Flight on Afterburner-Equipped Airplanes, L. Stewart Rolls and C. Dewey Havill | *Jan.* | 45 |
| Optimization of Power-Plant and Airplane Performance—A Symposium | *June* | 42 |
| Optimization Studies on Propulsion Systems for High-Speed Aircraft, Abe Silverstein | *June* | 53 |
| Propulsion Requirements for Navy Jet Fighters, Robert L. Hall | *June* | 42 |
| Turboprop Engines for Tomorrow's Transport, E. F. Heaton, C. S. Constantino, and W. H. Ziegler | *Mar.* | 62 |
| **Flight Simulators—** | | |
| The Role to Be Played by Training Devices in the Training of Aviation Personnel, Edmund O. Carmody | *May* | 74 |
| Use of Flight Simulators in the Design of Aircraft Control Systems, H. Elmore Blanton | *Feb.* | 29 |
| The Use of an Operational Flight Trainer as a Research Tool for Aircraft Instrumentation and Cockpit Rearrangement, Joseph N. Pecoraro | *May* | 86 |
| **Flight Testing—** | | |
| The Application of Flight-Test Techniques to Air-Load Distribution and Structural Research, Verlyn G. Marth | *Sept.* | 76 |
| The Flight-Test Organization, F. E. Christofferson | *June* | 62 |
| A Method of Locating the Airplane Take-Off Point and Determining the Take-Off Speed, Jerome M. Schwarzbach, John P. Boston, and Joseph E. Jenkins | *July* | 42 |
| FOX, N. L., AND S. J. HARVEY. Effect of Aircraft Jet-Engine Exhaust Impinging on Airfield Surfaces | *July* | 26 |
| FULLER, R. G. Report of Technical Sessions—1954 National Summer Meeting | *Oct.* | 42 |
| GRANHOLM, JACKSON W. The Use of Closed-Curve Equations of Variable Degree in Airplane Fuselage Lofting | *July* | 52 |
| HABER, HEINZ. Man and Machine Between Atmosphere and Space | *Nov.* | 56 |
| HALE, FRANK C. Human Factors in Jet-Transport Design | *Oct.* | 84 |
| HALL, ROBERT L. Propulsion Requirements for Navy Jet Fighters | *June* | 42 |
| HARVEY, S. J., AND N. L. FOX. Effect of Aircraft Jet-Engine Exhaust Impinging on Airfield Surfaces | *July* | 26 |
| HAVILL, C. DEWEY, AND L. STEWART ROLLS. Method for Measuring Thrust in Flight on Afterburner-Equipped Airplanes | *Jan.* | 45 |
| HEATON, E. F., C. S. CONSTANTINO, AND W. H. ZIEGLER. Turboprop Engines for Tomorrow's Transport | *Mar.* | 62 |
| HEINEMANN, E. H. Practical Considerations in the Optimization of Airplane and Engine Performance | *June* | 44 |
| HITCHCOCK, L. M. Development of Optimum Structure for Large Aircraft | *Nov.* | 50 |
| HOBBS, LEONARD S. Up and Down and Round and Round (*Editorial*) | *Oct.* | 38 |
| **Institute of the Aeronautical Sciences—** | | |
| 1954 AEDC Industry and Educational Advisory Board | *Mar.* | 40 |
| AGARD's Third General Assembly and Aeronautical Seminar | *Jan.* | 23 |
| AHS Milestone | *Jan.* | 64 |
| Air Flight Structures Study Center Established at Columbia University | *Jan.* | 63 |
| Air Safety Achievement Awards Presented | *Feb.* | 61 |
| American Non-Gran Becomes IAS Corporate Member | *Nov.* | 38 |
| AMS National Meeting | *Nov.* | 38 |
| Annual Business Meeting of the Institute | *Mar.* | 35 |
| ASME-SAE-IAS Fiftieth Anniversary Luncheon | *Feb.* | 20 |

| | Month | Page |
|---|---|---|
| **Institute of the Aeronautical Sciences,** *Continued*— | | |
| ASTIA Testing New Indexing System | *Jan.* | 63 |
| Automatic Control Courses Announced | *May* | 103 |
| Aviation Crash Injury Research Joins Cornell-Guggenheim Aviation Safety Center | *May* | 103 |
| 1953 Aviation Safety Award Winners | *Sept.* | 39 |
| Bane and Chanute Awards Presented | *Aug.* | 25 |
| A Brief Summary of the National Turbine-Powered Air Transportation Meeting | *Nov.* | 36 |
| CAI-IAS International Conference | *Dec.* | 36 |
| Consulting Firm of R. Dixon Speas Becomes Corporate Member | *May* | 52 |
| Director's Report—1953 | *Mar.* | 38 |
| Douglas Engineers Honored | *Jan.* | 63 |
| Eight Aeronautical Companies "Excellently Managed" | *Apr.* | 36 |
| Fairchild Announces Jet Transport Plans | *Jan.* | 23 |
| Fellowships in the Institute | *Mar.* | 43 |
| Fifth Southeastern Student Branch Conference | *Aug.* | 28 |
| Four IAS Members Among ION Executive | *Oct.* | 36 |
| Fourth International Aeronautical Conference | *Jan.* | 19 |
| Grant for New Guggenheim Fellowships Announced | *Feb.* | 21 |
| Guggenheim Fellowships Awarded at CalTech. | *July* | 21 |
| Guggenheim Fellowships at Princeton | *Sept.* | 39 |
| 1954 Guggenheim Medalist | *Nov.* | 38 |
| Honorary Fellows for 1953 | *Mar.* | 43 |
| IAFS Technical Director Named; IAS Members Assisting | *July* | 23 |
| IAS Awards and Honors for 1953 | *Mar.* | 44 |
| IAS Flight-Test Engineering Fellowship Announced | *Aug.* | 26 |
| IAS Members Elected SSA Officers | *Dec.* | 38 |
| IAS Members Head National Aeronautical Honorary Society | *Apr.* | 36 |
| IAS Members Serve with NACA | *May* | 52 |
| IAS Officers for 1954 | *Mar.* | 42 |
| IAS Twenty-Third Annual Meeting | *Dec.* | 35 |
| IAS Welcomes New Corporate Member | *July* | 23 |
| Institute of Air Flight Structures' Advisory Council Formed | *June* | 37 |
| International Geophysical Year Program; IAS Members Named to U.S. Committee | *June* | 38 |
| Israeli Aeronautical Engineers Form Society | *Oct.* | 36 |
| Jerome C. Hunsaker Professorship | *Sept.* | 39 |
| Longren Aircraft Joins IAS | *Mar.* | 39 |
| Minta Martin Aeronautical Student Fund | *Aug.* | 26 |
| Musick Memorial Trophy Awarded to Sir Melvill Jones | *July* | 22 |
| Newly Elected Members of the Institute Council | *Mar.* | 46 |
| Nine IAS Corporate Members Back Procurement Course at Fordham University | *June* | 37 |
| Ninth Annual Flight Propulsion Meeting | *June* | 35 |
| Norwich University Names Aviation Advisory Board | *June* | 38 |
| Notes on IAS Luncheon Speeches | *Apr.* | 35 |
| Penn State to Present Short Courses | *Apr.* | 36 |
| Preliminary Announcement of 1954 Annual Summer Meeting | *May* | 51 |
| President's Report—1953 | *Mar.* | 35 |
| Reaction Motors Joins IAS | *Apr.* | 36 |
| Ryan Becomes IAS Corporate Member | *June* | 37 |
| SAE Wright Brothers Award | *June* | 38 |
| 1953 Safety Contest Winners | *June* | 38 |
| St. Louis Section's First Annual Student Paper Competition | *Aug.* | 27 |
| Second Annual Northeastern IAS Student Branch Convention | *July* | 22 |
| Second Southwestern Student Competition | *July* | 20 |
| Seventeenth Wright Brothers Lecture | *Feb.* | 19 |
| S.L.A. Translations' List | *July* | 23 |
| S.L.A. Translation Supplement Available | *Nov.* | 38 |
| Summer Meeting Report | *Sept.* | 35 |
| Swedish Engineer to Present Eighteenth Wright Brothers Lecture | *Nov.* | 35 |
| Tentative Program for CAI-IAS Meeting | *Oct.* | 35 |
| Tentative Program for National Telemetering Conference | *May* | 53 |
| Translations Pool Established | *Jan.* | 63 |
| Treasurer's Report—1953 | *Mar.* | 36 |
| Turbine-Powered Air Transportation Meeting | *July* | 19 |
| Turboprop Test Program Announced | *Mar.* | 40 |
| United Aircraft Executive Wins Collier Trophy | *Feb.* | 21 |
| U.S. Rubber Joins IAS | *May* | 52 |
| West Coast IAS Student Branch Conference and Industry-Faculty Conference | *Sept.* | 38 |
| **Instruments**— | | |
| The Operational Application of Automatic Pilots, Fred S. Bonney | *July* | 47 |
| Operational Telemetering—An Aid to Air Navigation, M. V. Kiebert, Jr. | *May* | 94 |
| IRVINE, CLARENCE S. The Air Weapon Systems in Operation | *Nov.* | 42 |
| JENKINS, JOSEPH E., JEROME M. SCHWARZBACH, AND JOHN P. BOSTON. A Method of Locating the Airplane Take-Off Point and Determining the Take-Off Speed | *July* | 42 |
| KIEBERT, M. V., JR. Operational Telemetering—An Aid to Air Navigation | *May* | 94 |
| KRESS, RALPH. An Air-Powered Servo-Actuator | *Jan.* | 52 |
| LACHMANN, G. V. Laminarization Through Boundary-Layer Control | *Aug.* | 37 |
| LINDBERGH, CHARLES A. Honors Night Dinner Address (*Editorial*) | *Mar.* | 48 |
| LINDSAY, RUSSELL H. Practical Expectations and Limitations of the Reliability Problem | *Oct.* | 65 |
| LÖFKVIST, HANS-ERIC. Aeronautical Research and Development in Sweden | *Dec.* | 68 |
| MAIER, LUCILLE F. Problems Encountered in Calculating Reliability | *Dec.* | 52 |
| MAIERSPERGER, WALTER P. General Design Aspects of Flight Refueling | *Mar.* | 52 |
| MANGURIAN, GEORGE N. Is the Present Aircraft Structural Factor of Safety Realistic? | *Sept.* | 63 |
| MARTH, VERLYN G. The Application of Flight-Test Techniques to Air-Load Distribution and Structural Research | *Sept.* | 76 |
| MARTIN, GLENN L. Excerpts from the Seventeenth Wright Brothers Lecture (*Editorial*) | *Feb.* | 22 |
| McGUIGAN, WILLIAM D. The Basis for Compromise Between Theoretical Performance and Operational Reliability | *Dec.* | 65 |
| **Meeting Reports**— | | |
| The Growing Interest in Space Travel (A Report on the Fifth International Astronautical Congress, Innsbruck, Austria, August 1–7, 1954) | *Nov.* | 67 |
| A Report on the Fourth General Assembly of AGARD | *Sept.* | 42 |

| | Month | Page |
|---|---|---|
| **Meeting Reports,** *Continued*— | | |
| Report of Technical Sessions—1954 National Summer Meeting, R. G. Fuller | *Oct.* | 42 |
| 22nd Annual Meeting—Summary of Technical Sessions | *Apr.* | 40 |
| MENDELSON, MYRON J. The Decimal Digital Differential Analyzer | *Feb.* | 42 |
| MERRILL, W. W., JR., AND B. L. MESSINGER. Compressor Bleed in Turbine-Powered Aircraft | *Sept.* | 50 |
| MESSINGER, B. L., AND W. W. MERRILL, JR. Compressor Bleed in Turbine-Powered Aircraft | *Sept.* | 50 |
| MEYER, JOHN H. Test Development of Structures Designed Understrength | *Oct.* | 54 |
| **Military Aviation**— | | |
| Aeronautical Research and Development in Sweden, Hans-Eric Löfkvist | *Dec.* | 68 |
| The Air Weapon Systems in Operation, Clarence S. Irvine | *Nov.* | 42 |
| Application of Operations-Research Techniques to Air-Borne Weapon System Planning, Robert A. Bailey | *Oct.* | 72 |
| Propulsion Requirements for Navy Jet Fighters, Robert L. Hall | *June* | 42 |
| **Necrology**— | | |
| James W. Adams | *Mar.* | 40 |
| Robert O. Bitner | *May* | 103 |
| Noel W. Bouley | *Apr.* | 37 |
| Gerald R. Brady | *Aug.* | 29 |
| Thomas P. Buckley | *Nov.* | 39 |
| Henry H. Budds | *May* | 103 |
| Dr. Karl T. Compton | *Sept.* | 89 |
| Daniel W. Drake | *Feb.* | 61 |
| Ralph N. DuBois | *Nov.* | 39 |
| Major Gen. Oliver P. Echols | *Aug.* | 29 |
| Volney C. Finch | *Apr.* | 37 |
| Henry P. Folland | *Nov.* | 39 |
| Eugene Gerhardt | *Dec.* | 38 |
| Benarthur C. Haynes | *Aug.* | 29 |
| Robert J. Minshall | *Nov.* | 39 |
| Richard L. Morgan | *Apr.* | 37 |
| John C. Newton | *May* | 103 |
| Herbert Olden | *July* | 23 |
| C. J. Stewart | *Sept.* | 89 |
| John R. Stiles | *Jan.* | 64 |
| H. V. Wright | *June* | 38 |
| Dr. A. F. Zahm | *Oct.* | 36 |
| PALL, DAVID B. Porous Metals in Aircraft | *July* | 36 |
| PECORARO, JOSEPH N. The Use of an Operational Flight Trainer as a Research Tool for Aircraft Instrumentation and Cockpit Rearrangement | *May* | 86 |
| PENNELL, MAYNARD L. Evolution of the Boeing Jet Tanker-Transport Design | *Aug.* | 32 |
| **Personnel Training**— | | |
| Personnel Training Required to Produce Large Quantities of High-Performance Aircraft, Leverett P. Wenk | *Apr.* | 53 |
| The Role to Be Played by Training Devices in the Training of Aviation Personnel, Edmund O. Carmody | *May* | 74 |
| PIERCE, E. F. Optimization of Airplane and Engine Performance | *June* | 52 |
| POSTLE, DAVID E. Design of the Transport Helicopter | *Mar.* | 70 |
| **Production**— | | |
| Personnel Training Required to Produce Large Quantities of High-Performance Aircraft, Leverett P. Wenk | *Apr.* | 53 |
| The Use of Closed-Curve Equations of Variable Degree in Airplane Fuselage Lofting, Jackson W. Granholm | *July* | 52 |
| RASPET, AUGUST. Application of Sailplane Performance Analysis to Airplanes | *Aug.* | 56 |
| RASPET, AUGUST, AND GLENN D. BRYANT. Flight Measurements of Trailing-Edge Suction on a Sailplane | *Jan.* | 26 |
| **Research**— | | |
| Aeronautical Research and Development in Sweden, Hans-Eric Löfkvist | *Dec.* | 68 |
| Calibrating the PBY-6A Airplane for Meteorological Purposes, Given Brewer | *Feb.* | 24 |
| The Decimal Digital Differential Analyzer, Myron J. Mendelson | *Feb.* | 42 |
| ROBERTS, HOWARD E. Design Features of the XH-26 "Jet-Jeep" Helicopter | *Jan.* | 37 |
| ROLLS, L. STEWART, AND C. DEWEY HAVILL. Method for Measuring Thrust in Flight on Afterburner-Equipped Airplanes | *Jan.* | 45 |
| ROSCOE, S. N. Designing the Cockpit for High-Speed Flight | *Dec.* | 47 |
| **Rotating Wing Aircraft**— | | |
| Design Features of the XH-26 "Jet-Jeep" Helicopter, Howard E. Roberts | *Jan.* | 37 |
| Design of the Transport Helicopter, David E. Postle | *Mar.* | 70 |
| Development of New Cargo Helicopters, Donald M. Thompson | *Aug.* | 63 |
| Development Problems of the Large Helicopter, L. L. Douglas | *Apr.* | 60 |
| Economic Considerations of the Transport Helicopter, James B. Edwards | *Apr.* | 76 |
| Operational Economics of Scheduled Helicopter Transportation, Robert L. Cummings, Jr. | *June* | 66 |
| RUMMEL, R. W. Airplane Design in Relation to Safety | *Apr.* | 70 |
| **Safety**— | | |
| Airplane Design in Relation to Safety, R. W. Rummel | *Apr.* | 70 |
| Is the Present Aircraft Structural Factor of Safety Realistic?, George N. Mangurian | *Sept.* | 63 |
| Management's Economic Interest in Safety, Carl M. Christenson | *Aug.* | 52 |
| SANDELIN, MARSHALL P. Liquid Cold-Plate Method for Cooling of Air-Borne Electronic Equipment | *May* | 82 |
| SCHWALENBERG, H. V. Fabrication Aspects of Large Structural Components | *Nov.* | 63 |
| SCHWARZBACH, JEROME M., JOHN P. BOSTON, AND JOSEPH E. JENKINS. A Method of Locating the Airplane Take-Off Point and Determining the Take-Off Speed | *July* | 42 |
| SHRADER, WELMAN A. Some Recent Developments in Aviation Electronics | *May* | 56 |
| SILVERSTEIN, ABE. Optimization Studies on Propulsion Systems for High-Speed Aircraft | *June* | 53 |
| **Structures**— | | |
| The Application of Flight-Test Techniques to Air-Load Distribution and Structural Research, Verlyn G. Marth | *Sept.* | 76 |

| | Month | Page |
|---|---|---|
| **Structures,** *Continued*— | | |
| Development of Optimum Structure for Large Aircraft, L. M. Hitchcock | *Nov.* | 50 |
| Fabrication Aspects of Large Structural Components, H. V. Schwalenberg | *Nov.* | 63 |
| Is the Present Aircraft Structural Factor of Safety Realistic?, George N. Mangurian | *Sept.* | 63 |
| Practical Expectations and Limitations of the Reliability Problem, Russell H. Lindsay | *Oct.* | 65 |
| Problems Encountered in Calculating Reliability, Lucille F. Maier | *Dec.* | 52 |
| Test Development of Structures Designed Understrength, John H. Meyer | *Oct.* | 54 |
| THOMPSON, DONALD M. Development of New Cargo Helicopters | *Aug.* | 63 |
| TIMMEL, F. G., AND F. A. BAKER. Magamps Applied to Aircraft Control Problems | *Nov.* | 46 |
| VAN DEN BOUWHUYSEN, J. N. A. Starting Loads in Supersonic Wind Tunnels | *Jan.* | 50 |
| WALKER, W. J. The World's Largest Wind Tunnel | *Mar.* | 80 |
| WELLS, DOYLE C. Cooling Supersonic Electronic Equipment | *May* | 70 |
| WENK, LEVERETT P. Personnel Training Required to Produce Large Quantities of High-Performance Aircraft | *Apr.* | 53 |
| WILLIAMS, ROBERT MAURICE. Design of an Airfoil Oscillator | *Oct.* | 80 |
| **Wind Tunnels**— | | |
| Design of an Airfoil Oscillator, Robert Maurice Williams | *Oct.* | 80 |
| Starting Loads in Supersonic Wind Tunnels, J. N. A. van den Bouwhuysen | *Jan.* | 50 |
| The World's Largest Wind Tunnel, W. J. Walker | *Mar.* | 80 |
| WOODS, R. J. Suggested Supersonic Design Considerations | *June* | 46 |
| ZIEGLER, W. H., E. F. HEATON, AND C. S. CONSTANTINO. Turboprop Engines for Tomorrow's Transport | *Mar.* | 62 |



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# Index to A


A

AC Spark Plug Division, General Motors Corporation ..... 5
Aerojet-General Corporation, Subsidiary of The General Tire & Rubber Company ..... 24
Aeronautical Engineering Catalog ..... 120, 126
Aeronautical Engineering Review ..... 126
Aeronca Manufacturing Corporation ..... 134
★Airborne Accessories Corporation ..... 85
Allison Division, General Motors Corporation ..... 17
★American Chemical Paint Company ..... 121
American Machine & Foundry Company, The Cleveland Welding Company Subsidiary ..... 21
★American Phenolic Corporation ..... 79
American Seating Company ..... 126
★American Steel & Wire Division, United States Steel Corporation ..... 115

B

B. H. Aircraft Company Inc. ..... 106
Bell Aircraft Corporation ..... 92
Bendix Aviation Corporation
★Bendix Products Division ..... 131
Red Bank Division ..... 100
★Borg-Warner Corporation, Pesco Products Division ..... Inside Back Cover

C

CalTech Jet Propulsion Laboratory ..... 134
★Cannon Electric Company ..... 77
Chandler-Evans Division, Niles-Bement-Pond Company ..... 102, 103
Cleveland Welding Company, The, Subsidiary of American Machine & Foundry Company ..... 21
Clifford Manufacturing Company Division, Standard-Thomson Corporation ..... 19
Convair Division, General Dynamics Corporation ..... 135
Cooper Precision Products ..... 127
Cornell Aeronautical Laboratory, Inc. ..... 134

D

Dow Chemical Company, The, Magnesium Department ..... 9

E

★Electrical Engineering & Manufacturing Corporation ..... 14, 15

F

Fairchild Engine and Airplane Corporation
★Fairchild Aircraft Division ..... 137
Fairchild Engine Division ..... 32
★Stratos Division ..... Back Cover
★Fenwal Incorporated ..... 16

G

General Dynamics Corporation, Convair Division ..... 135
General Electric Company ..... 112, 113
General Motors Corporation
AC Spark Plug Division ..... 5
Allison Division ..... 17
Harrison Radiator Division ..... 75
General Precision Equipment Corporation
Kearfott Company, Inc., Subsidiary ..... 83
Librascope, Incorporated, Subsidiary ..... 120
General Radio Company ..... 93
General Tire & Rubber Company, The, Aerojet-General Corporation Subsidiary ..... 24
Goodyear Tire & Rubber Company, Inc., Aviation Products Division ..... 1
Grumman Aircraft Engineering Corporation ..... 109, 135

H

Hagan Corporation ..... 30
Hamilton Standard Division, United Aircraft Corporation ..... 134
H. M. Harper Company, The, Aero Division ..... 119
Harrison Radiator Division, General Motors Corporation ..... 75
Hoffman Laboratories, Inc., Subsidiary of Hoffman Radio Corporation ..... 123

Indiana Gear Works, Inc. ..... 10
Imperial Tracing Cloth, Keuffel & Esser Company ..... 119
International Nickel Company, Inc., The ..... 29

J

★Jack & Heintz, Inc. ..... 8
Johns Hopkins University, The ..... 134
★Johns-Manville ..... 96

K

Kawneer Company, Aircraft Products Division ..... 82
Kearfott Company, Inc., Subsidiary of General Precision Equipment Corporation ..... 83
Keuffel & Esser Company, Imperial Tracing Cloth ..... 119
Walter Kidde & Company, Inc. ..... 11
Kollsman Instrument Corporation, Subsidiary of Standard Coil Products Company, Inc. ..... 105

L

★Lamb Electric Company, The ..... 108
★Lear, Inc., Lear-Romec Division ..... 81
Librascope, Incorporated, Subsidiary of General Precision Equipment Corporation ..... 120
Lockheed Aircraft Corporation ..... 88, 89, 128, 132

# Advertisers


M

Manning, Maxwell & Moore, Inc., Aircraft Products Division ..... 111
Glenn L. Martin Company, The ..... 135
★Meletron Corporation ..... 117

N

National Forge and Ordnance Company ..... 26
★New York Air Brake Company, The, Watertown Division ..... 13
Niles-Bement-Pond Company, Chandler-Evans Division ..... 102, 103
North American Aviation Inc. ..... 134, 135
Northrop Aircraft, Inc. ..... 95

P

Pastushin Aviation Corporation ..... 12
★Pesco Products Division, Borg-Warner Corporation ..... Inside Back Cover
Pittsburgh Plate Glass Company ..... 119

R

Radio Corporation of America ..... 28, 124
Reaction Motors, Inc. ..... 20
Red Bank Division, Bendix Aviation Corporation ..... 100
Republic Aviation Corporation, Guided Missiles Division ..... 136
★Rohr Aircraft Corporation ..... 18

S

Sanborn Company, Industrial Division ..... 27
Sargent Engineering Corporation ..... 98
★Simmonds Aerocessories, Inc. ..... 91
★The Sperry Corporation, Vickers Incorporated Division ..... 138
Standard Coil Products Company, Inc., Kollsman Instrument Corporation Subsidiary ..... 105
★Standard Pressed Steel Company, Aircraft Products Division ..... 4
Standard-Thomson Corporation, Clifford Manufacturing Company Division ..... 19
★Stratos Division, Fairchild Engine and Airplane Corporation ..... Back Cover
Sundstrand Aviation Division, Sundstrand Machine Tool Company ..... Inside Front Cover
Surface Combustion Corporation, Aircraft-Automotive Division ..... 6, 7

T

★Thompson Products, Inc., Electronics Division ..... 114

U

United Aircraft Corporation, Hamilton Standard Division ..... 134
United States Aviation Underwriters, Inc. ..... 120
★United States Steel Corporation, American Steel & Wire Division, Columbia-Geneva Steel Division, Tennessee Coal & Iron Division, U. S. Steel Export Company Division ..... 115

V

★Vickers Incorporated Division, The Sperry Corporation ..... 138

W

Waldes Kohinoor, Inc. ..... 25
Wallace & Tiernan Incorporated ..... 126
★Watertown Division, The New York Air Brake Company ..... 13
Weber Aircraft Corporation, Subsidiary of Weber Showcase & Fixture Co., Inc. ..... 107
★Western Gear Works ..... 87
Westinghouse Electric Corporation ..... 22, 23, 129
★Weston Electrical Instrument Corporation ..... 31
★Wittek Manufacturing Company ..... 94
Wyman-Gordon Company ..... 146



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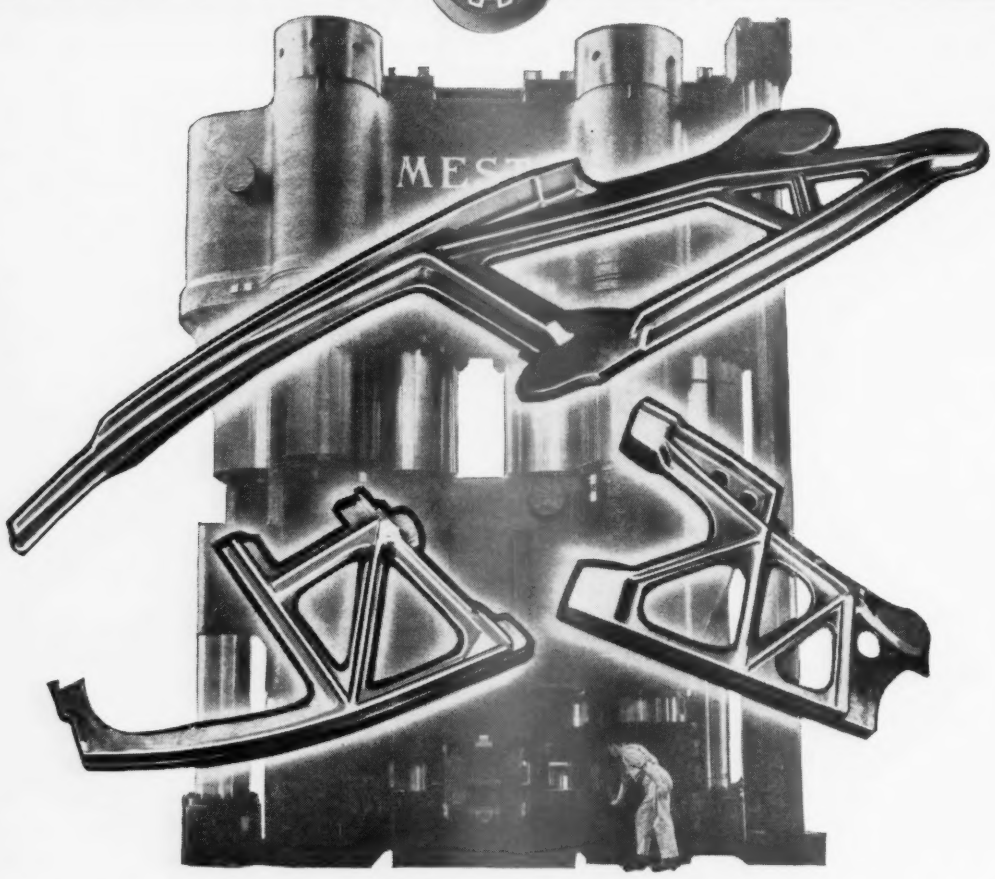

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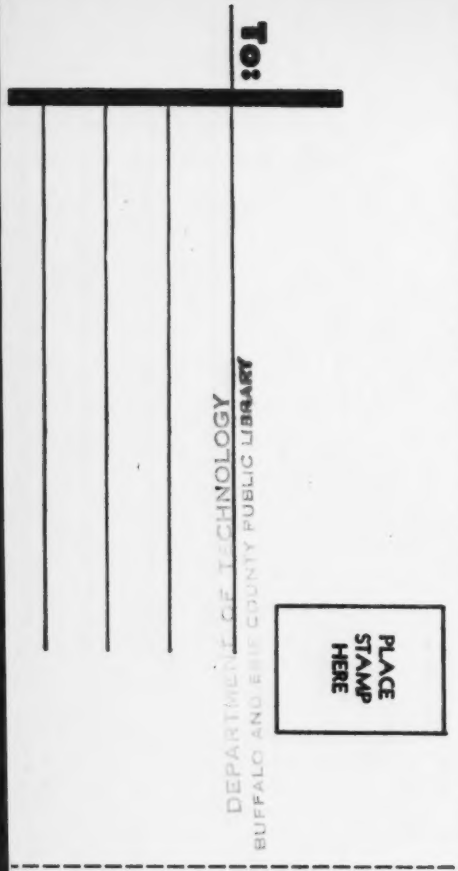


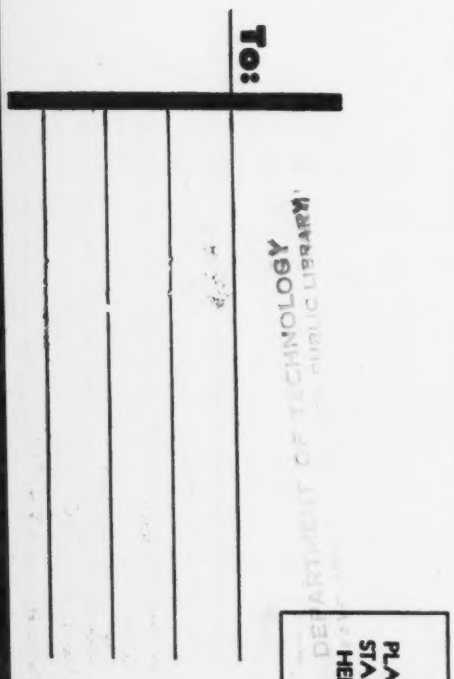


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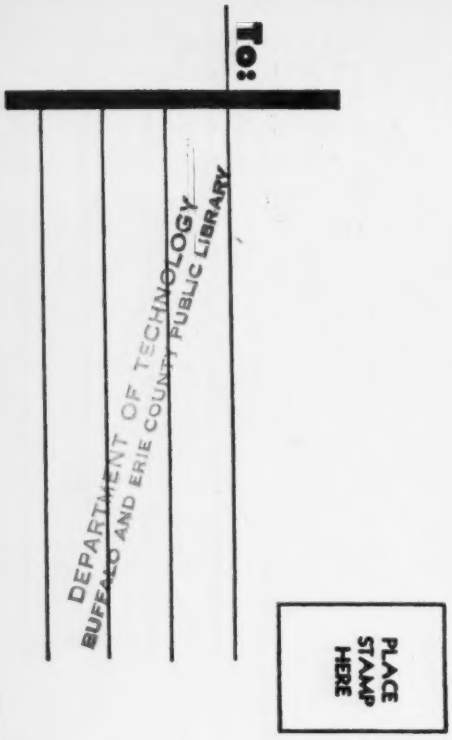


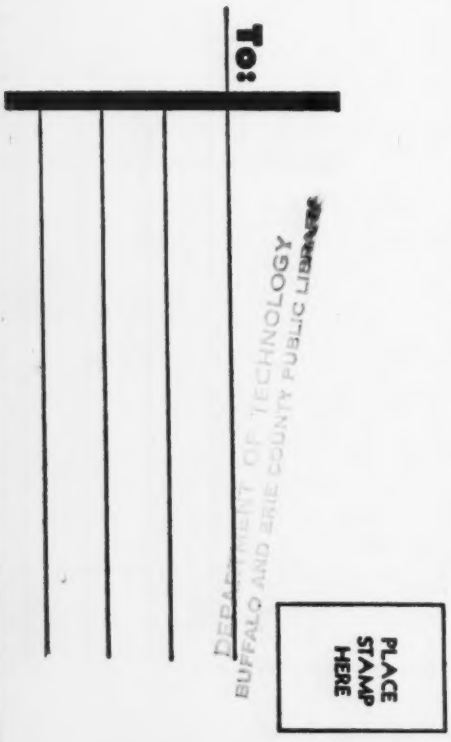


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## NEW LITERATURE OFFERED BY ADVERTISERS

**"Fastenings of High Temperature & Corrosion-Resistant Alloys."** Bulletin HTA. **H. M. Harper Co., 8282 Lehigh Ave., Morton Grove, Ill.** *See page 119*

**"Report from Hoffman Laboratories."** Electronics brochure. **Hoffman Laboratories, Inc., 3761 S. Hill St., Los Angeles 7, Calif.** *See page 123*

**Optical Systems & Components.** Brochure entitled "2076 Eyes." **Kollsman Instrument Corp., 80–16 45th Ave., Elmhurst, N.Y.** *See page 105*

**"150" Recording Systems.** Catalog and technical data. **Sanborn Co., Industrial Div., Cambridge 39, Mass.** *See page 27*

**Aircraft Hydraulic Equipment.** Bulletin No. A-5200-B. **Vickers, Inc., 1414 Oakman Blvd., Detroit 32, Mich.** *See page 138*

**Aneroid Manostat.** Publication No. TP-12-A. **Wallace & Tiernan Inc., 25 Main St., Belleville 9, N.J.** *See page 126*

**Sensitrol Relays.** Bulletin. **Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.** *See page 31*

The principle of electrothermal de-icing was developed by the National Research Council of Canada. The difficult propeller application was solved through the pioneering teamwork of Goodyear and Hamilton Standard of Windsor Locks, Connecticut. *Goodyear—a great name to work with TO GET RESULTS!*

**Ten years ago,** Hamilton Standard and Goodyear joined forces to do battle with ice—long a bitter enemy of the aircraft propeller.

**It was pioneering effort** which overcame technical difficulties that for years had stumped every aeronautical engineer who had sought a foolproof method for de-icing the whirling blades.

**Out of this teamwork,** the blade Iceguard was born—a new electrothermal system utilizing thin plies of electrically conductive rubber, power-fed by fatigue-resistant braided wire leads from a unique "pigtail" power connection.

THIN, the Iceguard conformed readily to blade contours — maintained the aerodynamic contour of the propeller. TOUGH, the homogeneous structure of the conductive rubber resisted rain and erosion—increased life of the de-icing equipment. EXTREMELY EFFICIENT, the Iceguard proved to be the most nearly perfect sheet-type heater because the thermal gradient across the heater is minimized.

And above all, RELIABLE. Today, as a result of the continued design and test work by Hamilton Standard, Goodyear and the help of the National Research Council of Canada, these famous propellers equipped *with Iceguards have logged 20 billion blade air miles and 65 million blade flying hours in actual service!*

It is convincing proof of performance, a tribute to Hamilton Standard's pioneering leadership—the kind which has placed their blades "out front" on the finest, fastest reciprocating-engine aircraft in the world!

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Iceguard—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio

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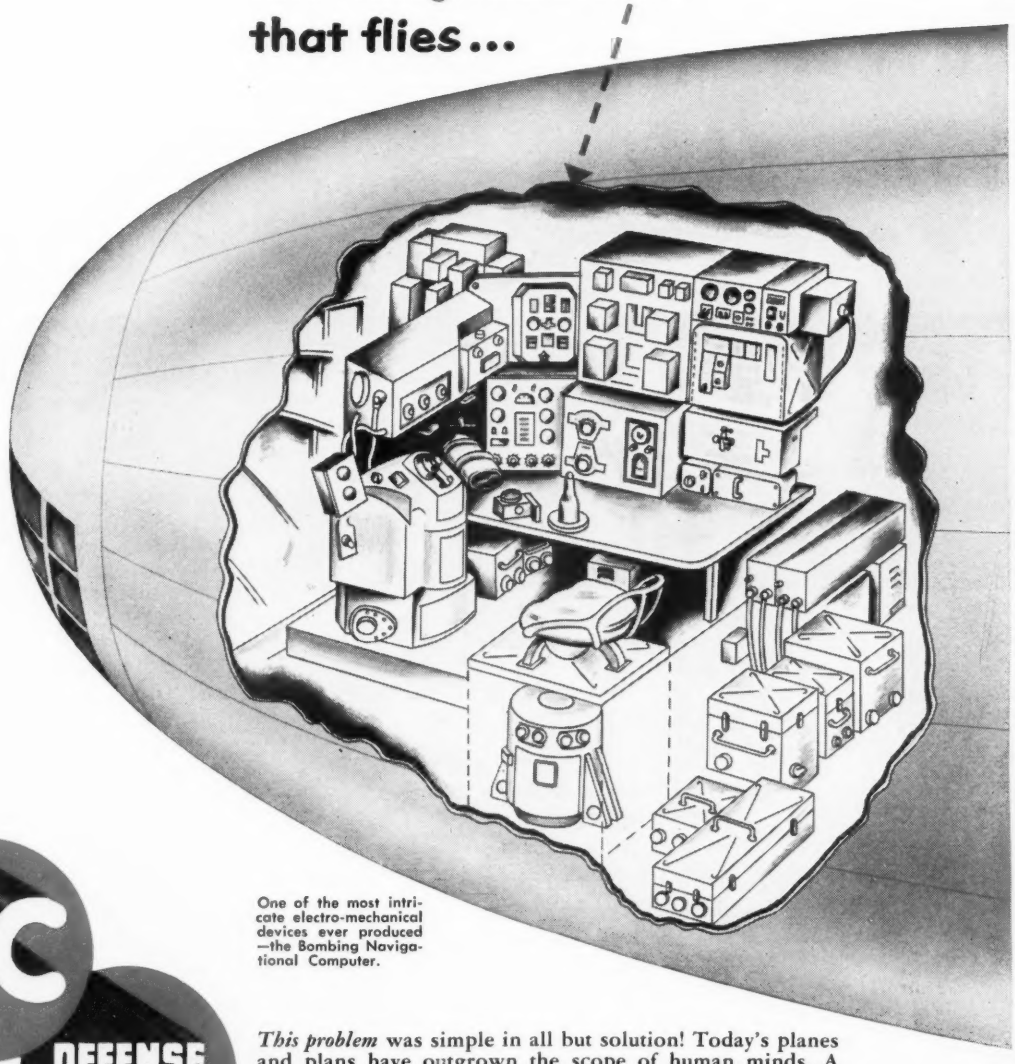
# SOLVED:

## the problem of the "thinking machine" that flies...



One of the most intricate electro-mechanical devices ever produced —the Bombing Navigational Computer.

AC DEFENSE PRODUCTS

GM GENERAL MOTORS

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GENERAL MOTORS CORPORATION
FLINT, MICHIGAN

*This problem* was simple in all but solution! Today's planes and plans have outgrown the scope of human minds. A device had to be developed to solve complex aerial navigation and bombing problems with superhuman speed and accuracy. Yet, this device must still be light enough to fly.

*The answer* is now coming off the production lines of AC's Milwaukee plant—the Bombing Navigational Computer. Through miles of complex wiring, electronics now can home planes in on targets with unerring skill.

AC's contribution—in the three fields of research, development and production—is another example of know-how in action. AC's exceptional engineering staff and unique facilities are as close as your phone. Why not consult AC?

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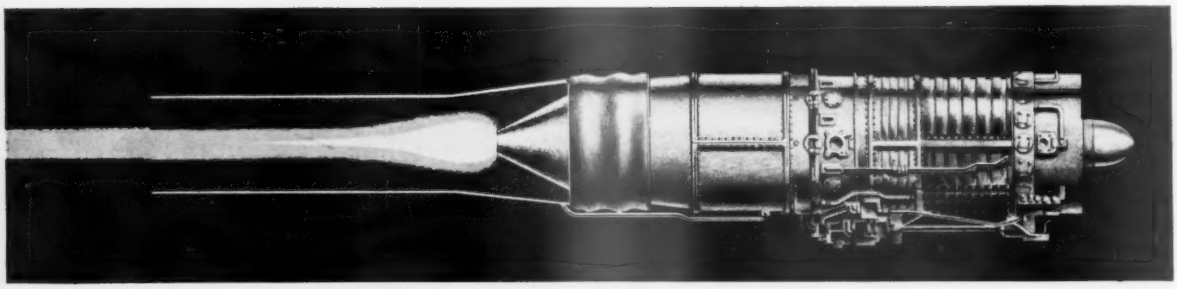
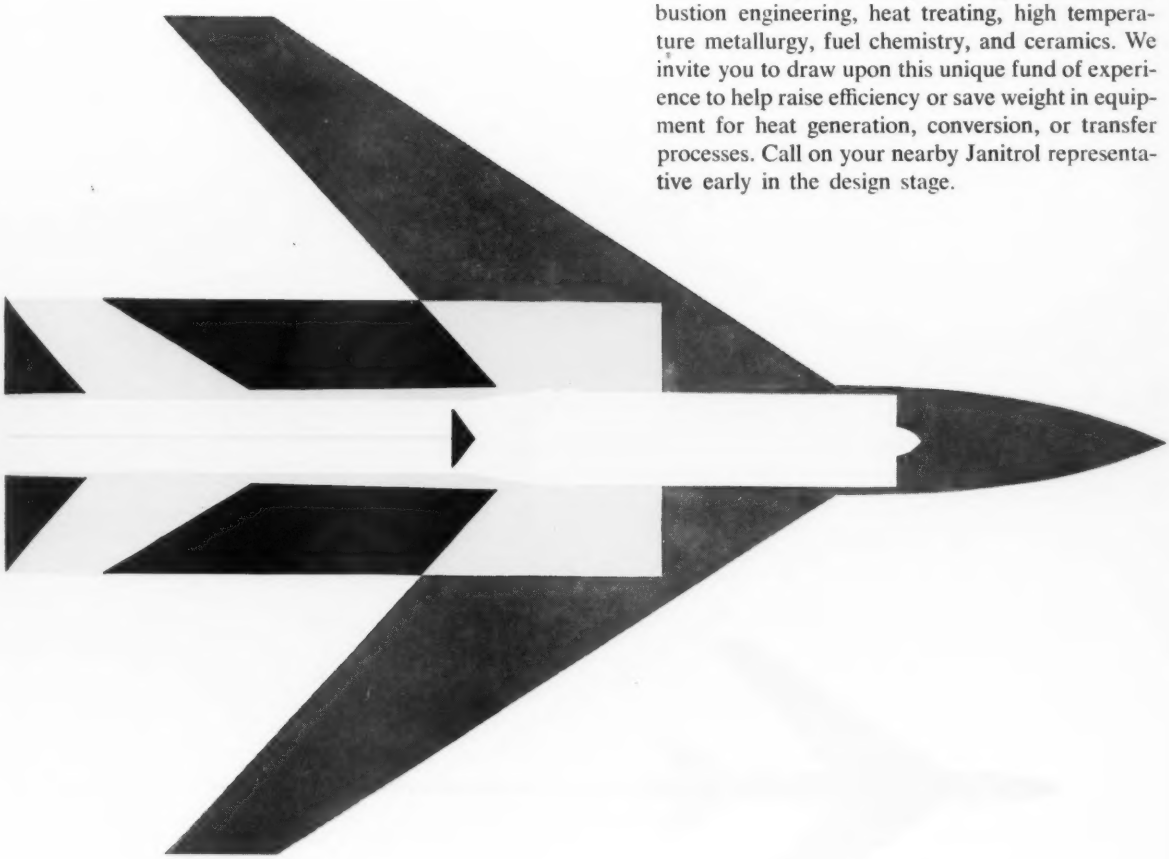


The addition of extra thrust to new jet engines with a combustion device weighing only six pounds is one of today's major engineering achievements—the result of successful collaboration between Janitrol and gas turbine manufacturers.

Aside from its amazing light weight, chief features of the new Janitrol Post-Turbine Burner are ease and simplicity of installation, long life, high efficiency, and ability to be turned on and off repeatedly as required. In its present stage of development, this Janitrol combustion equipment gives the aircraft engine designer a new dimension of power – and current progress indicates a good potential for even greater power gains, with negligible addition of weight.

This development is a concrete example of Janitrol pioneering – another of Janitrol's many "firsts" which include the whirling flame heater, the radiant tube heating principle–hot rod wing anti-icing–purge gas generators–canopy seal regulators–and the dimple plate construction of heat exchangers. The background necessary for these contributions has not been acquired overnight: rather, it goes back over 37 years and spans many fields of combustion engineering, heat treating, high temperature metallurgy, fuel chemistry, and ceramics. We invite you to draw upon this unique fund of experience to help raise efficiency or save weight in equipment for heat generation, conversion, or transfer processes. Call on your nearby Janitrol representative early in the design stage.



*37 years experience in combustion engineering*

Janitrol

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SURFACE COMBUSTION CORPORATION

*Columbus 16, Ohio*

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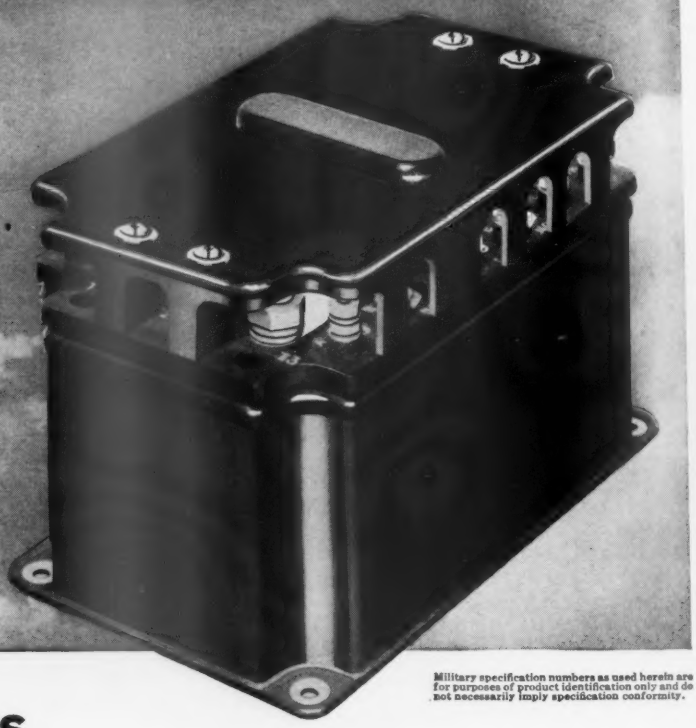
# NEW A-C CIRCUIT BREAKER



Military specification numbers as used herein are for purposes of product identification only and do not necessarily imply specification conformity.

## 4 FEATURES make J&H unit ideal for aircraft application!

An important component in the complete Jack & Heintz a-c system "package," the new J & H Type GC86 Circuit Breaker is designed to MIL-C-8379. The new breaker meets dimensional and performance requirements of the specifications and *weighs but 4.5 pounds.* It can be supplied as an individual component if desired.

**1. Balanced Rotary Latch**
Latch employs "over-center" principle with roller bearing as latching surface. This design reduces energy necessary to trip latch and insures that breaker remains latched in extreme shock conditions.

**2. Direct Solenoid-Actuated Contacts**
Main contacts are connected directly to plunger of closing solenoid. No levers or highly loaded bearings are required for contact actuation. Wear is eliminated through absence of both fulcrums and plastic contact-actuation points. The contact's long operating stroke eliminates frequent adjustment for accuracy.

**3. Positive Anti-Pump Circuit**
Interlock relay provides positive anti-pump circuit. Adjustment of interlock contacts is noncritical.

**4. Easier Contact Inspection**
Special construction allows inspection of main contacts without disassembly of breaker.

Jack & Heintz engineering personnel and manufacturing facilities are geared to undertake design and production of complete a-c systems or individual components. We invite your inquiry. Write Jack & Heintz, Inc., 17632 Broadway, Cleveland 1, Ohio.

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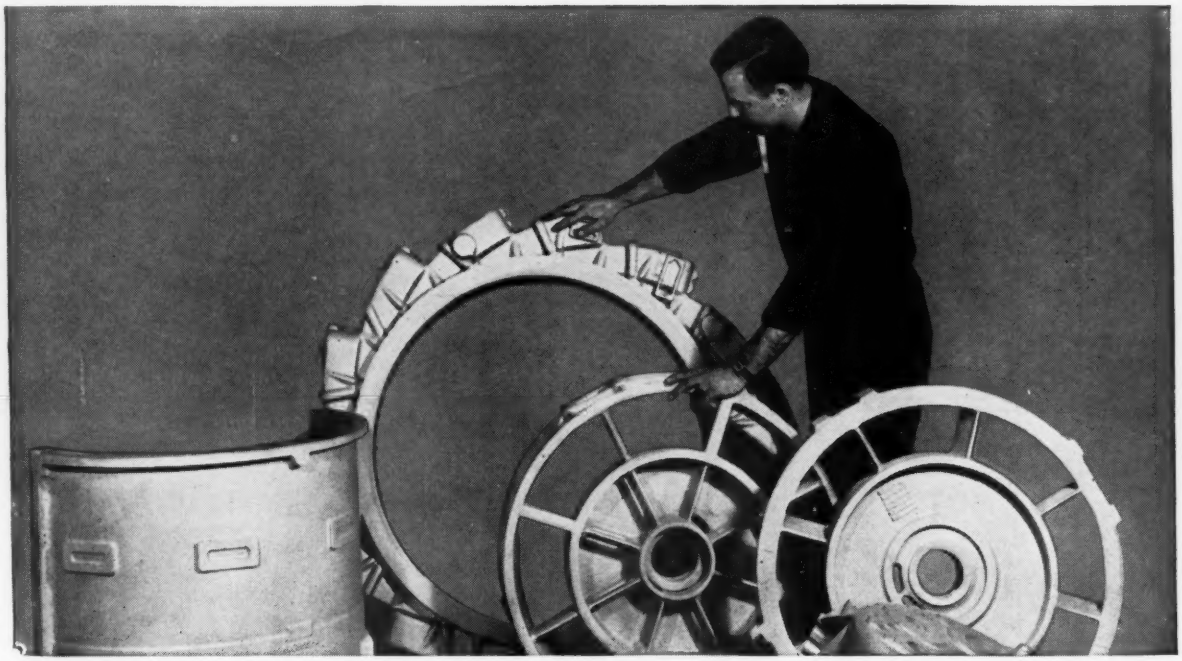
JACK & HEINTZ *Rotomotive* AIRCRAFT EQUIPMENT

DOW

# LIGHTER, MORE RIGID CASTINGS MADE WITH DOW MAGNESIUM

## Production economies also offered by sand and permanent mold castings



Lighter, yet more rigid castings! That's the big advantage of magnesium in sand and permanent mold castings.

By increasing section thickness and adding stiffening ribs, greater rigidity is possible. And because of magnesium's high strength to weight ratio, total weight can be cut.

Magnesium also offers outstanding production advantages. Chief among these is magnesium's excellent machinability. There are many instances where time saved in machining has lowered the cost of the finished part beyond that of any other metal. Cutting tools last longer; replacement costs and downtime for sharpening and resetting are reduced.

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For further information on the advantages of magnesium, contact your nearest Dow sales-office or write THE DOW CHEMICAL COMPANY, *Magnesium Department*, Midland, Michigan.

***you can depend on DOW MAGNESIUM***

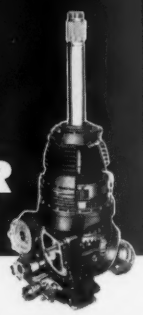
DOW

. . . and then we built

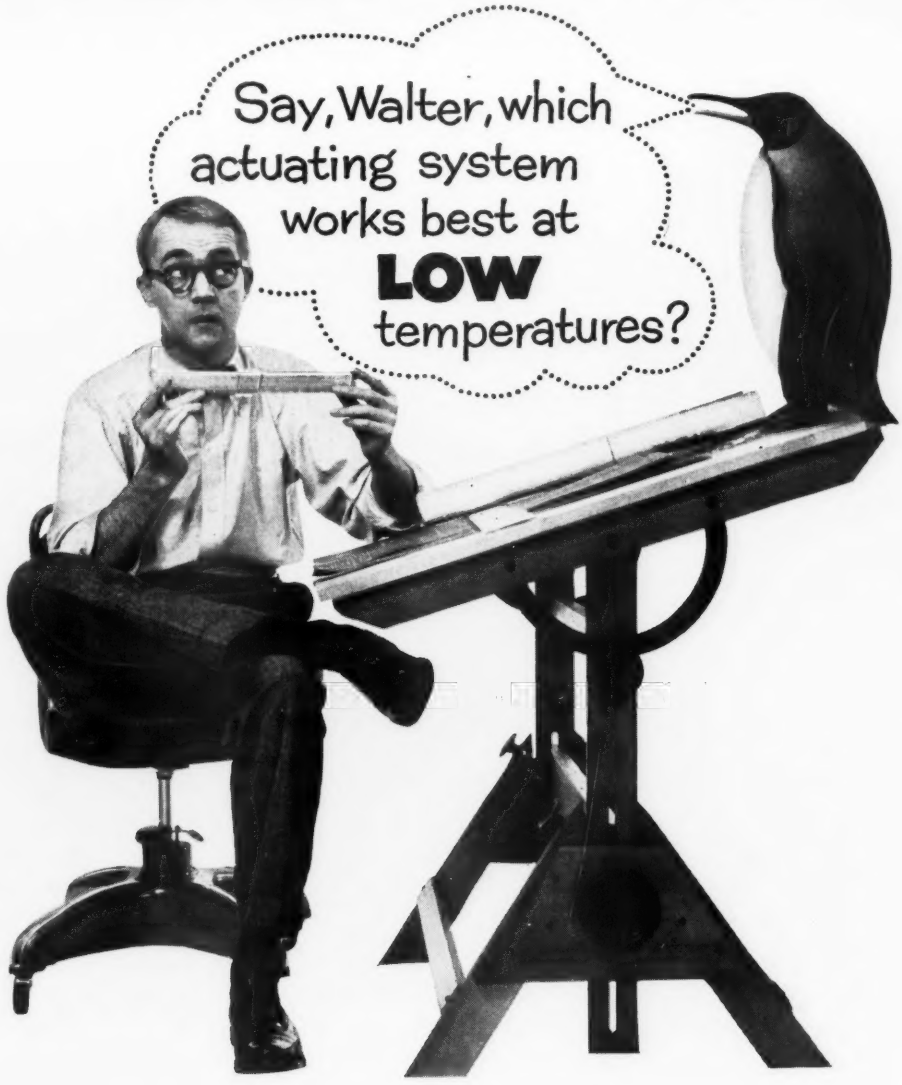
*the main rotor transmission for the S-55 Sikorsky Helicopter.*

High on the list of "things we are proud of" at IGW is the transmission shown here (demonstration cut-a-way). Precision built to transmit 700 H. P. with an input speed of 2400 RPM and a reduction ratio of 11.348 to 1. In spite of high stresses and great complexity the service life of this transmission has been outstanding.

INDIANA GEAR



INDIANA GEAR WORKS, INC. • INDIANAPOLIS, INDIANA




For fast, efficient performance at temperatures as low as −65°, consider pneumatics! Viscosity of the air used in pneumatic systems remains essentially the same over an extremely broad temperature range. From −65° to +250°, the system is *never* sluggish.

Only pneumatics *stores* energy and delivers it *instantly* when you need it, with no weight penalty. You get *high* horsepower delivery from a *low* horsepower source, with considerable saving in weight. You also save space, since pneumatic systems use smaller lines, with *no* return lines required.

With pneumatics, there is no danger from fire, since the air used in the system cannot burn. And leakage is no serious problem. Air is always available, and the compressor itself will compensate for any minor leaks which might occur.

We here at Kidde have a *complete* line of pneumatic system components, as well as the facilities for engineering complete pneumatic systems. If *you* have a problem in pneumatics, please write us.

**Kidde**
**FOR PNEUMATICS**

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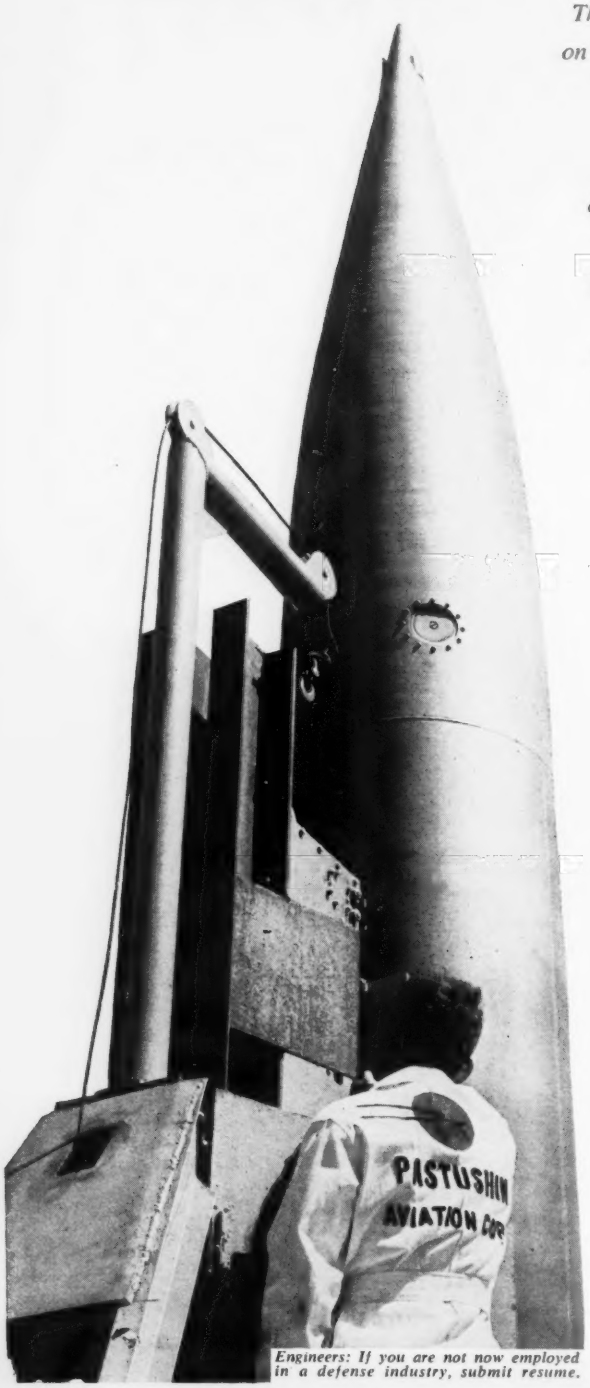
*Thousands of "firings" on Pastushin Aviation's outdoor Firing Test Stand testify to the operational efficiency of the Pastushin force ejection system consisting of ejection mechanisms and external stores.*




*Engineers: If you are not now employed in a defense industry, submit resume.*

Pastushin assures complete jettisonable reliability by stringent tests on its own equipment. Static, slosh and vibration and force ejection tests qualify all external tanks; environmental, static and firing tests prove out all ejection mechanisms. Finally, air-drops furnish conclusive proof of the system's reliability in forcibly ejecting bombs, jettisonable fuel tanks and other external stores. Ready now to your special requirements.

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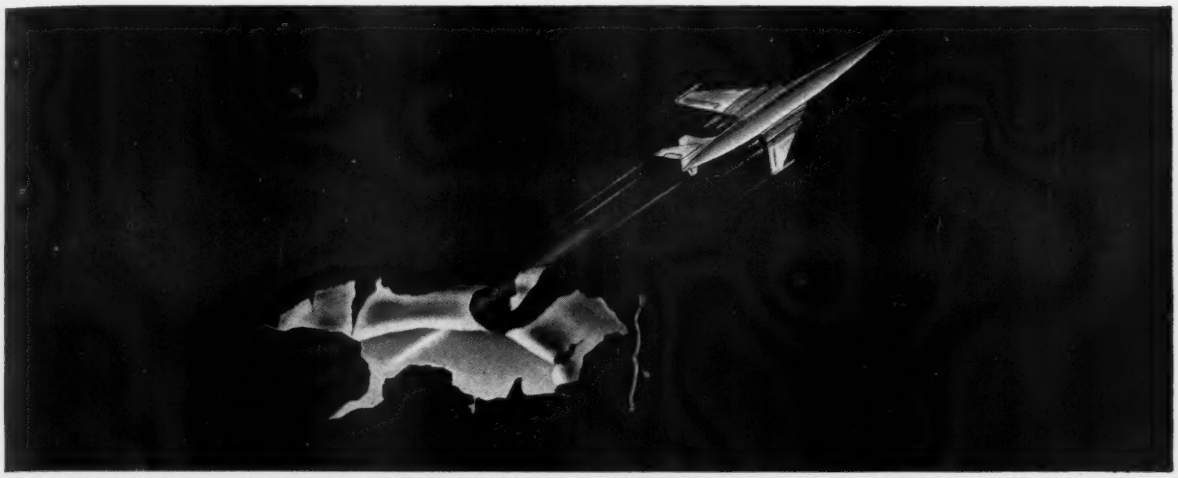
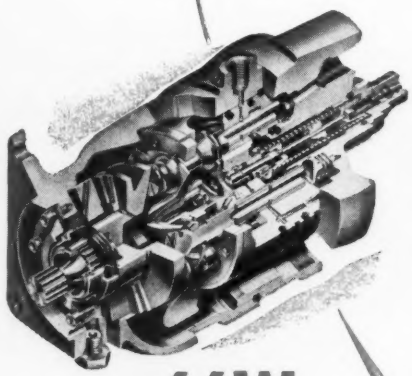


# STRATOPOWER Is Ready for the Planes Which Will Break Through Today's Ceilings

The modern STRATOPOWER Hydraulic Pumps are ready and able to perform efficiently well beyond heights penetrated by piloted aircraft. They've proved it! In Rockets, Guided Missiles and under the simulated conditions of the ionosphere STRATOPOWER Pumps *pump!* They are built to perform at full efficiency and with complete dependability under the extreme conditions and variables imposed by projected speeds and service ceilings.

STRATOPOWER Pumps draw fluid from unpressurized reservoirs to sustain system pressure at altitudes where other pumps, dependent upon pressurized reservoirs, would be unable to supply system demands. Thus, they afford that vital added safety factor for high altitude operation . . . system actuation is assured, even though reservoir pressure may be lost.



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**PRESSURE COMPENSATED HYDRAULIC PUMPS**

Designed to simplify hydraulic systems and to render the exacting control of such circuits more dependable. The range of models in these variable delivery pumps includes sizes delivering from 2 to 10 gpm at 1500 rpm with operating pressures to 3000 psi and speeds to 4500 rpm.

*There is a STRATOPOWER Hydraulic Pump to provide the efficient source of fluid power for your requirement. Write for full information today.*

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# MOTORS

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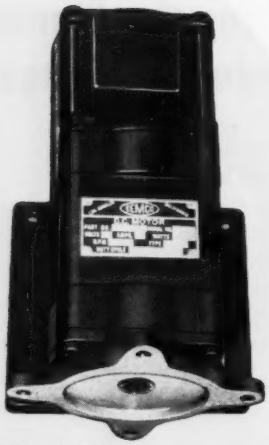
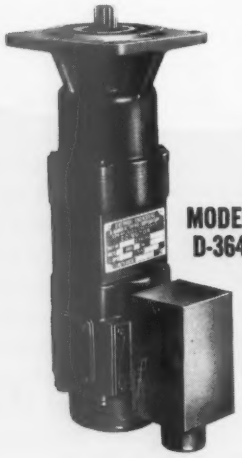
**Greater power output per pound of weight is the constant objective of motor design engineers at EEMCO. In addition, they strive continually to produce smaller motors with decreased weight thus aiding aircraft designers two ways in their ceaseless drive to reduce both size and weight. Shown here are but a few of the motors EEMCO has produced for leading airframe manufacturers and their suppliers. Virtually all of the newest jet aircraft being built for the U. S. Air Force are equipped with EEMCO motors . . . or with one or more of the many types of linear and rotary actuators also designed and manufactured by EEMCO. Your inquiry is invited.**



MODEL D-479

MODEL C-1076



MODEL D-364

MODEL C-875

**MODEL D-479: EMERGENCY MOTOR FOR HYDRAULIC SYSTEMS ON INTERMITTENT DUTY**

Operates to 160°F. Ambient temperature on a duty cycle of 1½ min. at 25.6 inch lbs., 5 min. at 8.0 inch lbs., then 30 min. rest period. Turns up 5500 r.p.m. on 24 volt D.C. at 90 amperes, with 2.75 HP output. Explosion proof. Weight: 14.75 lbs.

**MODEL C-1076: SMALL VALVE MOTOR**

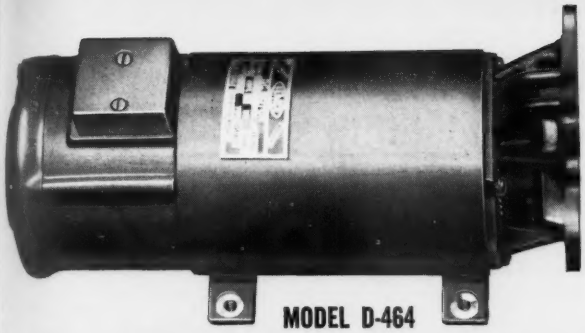
Only 2½" long x 1¾" x 1½"; weighs but 11.7 ounces. Operates on 26 volt D.C. at 2.9 amperes at 21,000 r.p.m. on split series, reversible. Output is 25 watts.

**MODEL D-364: WING FLAP MOTOR FOR LARGE JET FIGHTER**

Operates at 7400 r.p.m. on 26 volt D.C. at 62 amperes with 1.25 HP output. Has clutch and brake with static brake torque of 20 inch lbs., thermal protector, radio noise filter, is explosion proof. Weight: 11.2 lbs.

**MODEL C-875: TWO SPEED RADAR ANTENNA AZIMUTH MOTOR**

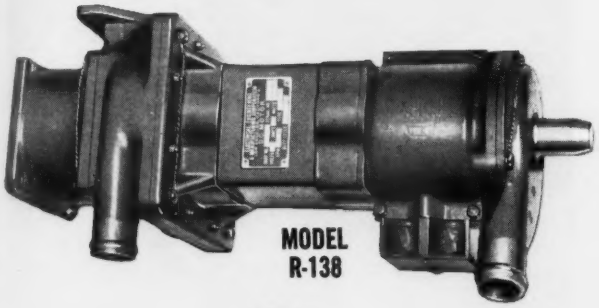
designed for continuous duty to operate at 3300 and 13,200 r.p.m. on 26 volt D.C. Rugged in construction, yet compact in size, it has a life of 2,000 hours. Weight: 2.75 lbs.



MODEL D-464

**MODEL D-464: EMERGENCY STAND-BY MOTOR**

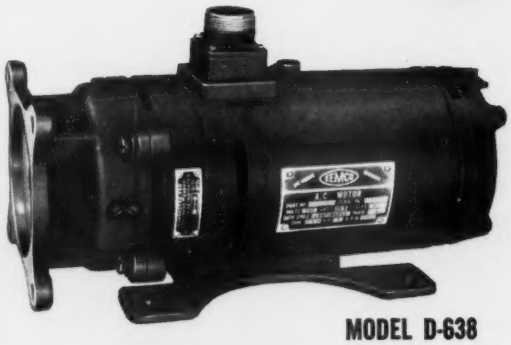
for use on Supersonic Research Aircraft. Designed to operate at high ambient temperature of 70°C. at 50,000 foot altitudes. Duty cycle is 1 minute at 1 HP, 30 seconds at 2½ HP. High temperature materials used throughout. Motor weight, including gear box: 22½ lbs.



MODEL R-138

**MODEL R-138: EXPLOSION-PROOF HYDRAULIC PUMP DRIVE**

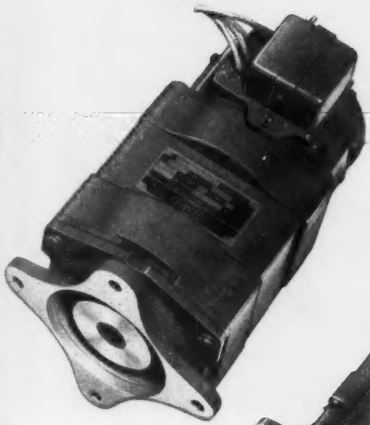
equipped with in-line gear reduction. Gear box designed to keep acoustic noise level at an absolute minimum. For continuous duty operation with duty cycle varying from 1½ to 5 HP load. Designed to operate for 2,000 hours without maintenance. Operates in a vertical position. Weight; 20½ lbs.



MODEL D-638

**MODEL D-638: 400 CYCLE, 6.5 HP, A.C. MOTOR FOR INTERMITTENT DUTY**

made to drive a hydraulic pump on a guided missile. Duty cycle is 3.0 seconds at 6.5 HP with 2250 r.p.m., 15.0 seconds at 1.5 HP. Has continuous rating of 5 HP at 2300 r.p.m., 15.8 amperes, 200 volts. Weight: 17½ lbs.



MODEL D-507

**MODEL D-507: MISSILE APPLICATION MOTOR**

This 2 HP, 115 volt D.C. motor provides 12,000 r.p.m. on continuous duty. An internal spline drive within the armature shaft allows for a close coupled, extremely compact assembly to drive a 400 cycle, 3 phase permanent magnet alternator. Provision is made in motor winding to maintain constant output speed with varying conditions of voltage and load. Unit is equipped with radio noise filter. Weight: 15.5 lbs.

MODEL C-1180

**MODEL C-1180: STAND-BY MOTOR FOR HORIZONTAL STABILIZER**

Has a duty cycle of 50 seconds on, 3 minutes off. Rated 13,000 r.p.m. on 25 volt D.C. at 21 amperes, with 0.5 HP output. Has 2 inch stack length. Weight: 4.25 lbs.

Designers and producers of
motors, linear and rotary actuators.

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**EEMCO can supply a motor to fit *your* specifications**

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**1. BREAKS SUPERSONIC SPEED RECORD.** On December 12, 1953 the rocket-powered Bell X-1A traveled 2½ times the speed of sound — or more than 1600 miles an hour. This record-breaking plane relies on Fenwal's newest Over-Heat Detectors to give instant warning of overheat conditions.

**2. WORLD'S LARGEST TRANSPORT HELICOPTER** is this twin-engine, tandem-rotor Piasecki H-16, recently unveiled by the U. S. Air Force. It carries 40 troops, 32 litter patients or three jeeps. The H-16 depends on Fenwal Midget THERMOSWITCH units to warn of overheating in transmission gear boxes, and THERMOSWITCH heater controls for cabin combustion heaters.

**3. FENWAL FIELD ENGINEERS** work directly with airframe, aircraft engine manufacturers, armed services and civilian airlines on the proper application of our products. Here, two Fenwal engineers confer with an Eastern Air Lines technician on special test equipment.

**4. AMONG THE LATEST FENWAL DEVICES** are those pictured here — used in the newest research, Air Force, and civilian airline planes. The shell is the fast-acting temperature-sensitive element in all Fenwal units. They include Fire Detectors, Regular and Midget Over-Heat Detectors and cabin Heater Controls, to meet all aircraft temperature control and detection requirements. For complete data write **Fenwal Incorporated, 1712 Pleasant St., Ashland, Mass.**

Fenwal

**THERMOSWITCH®**

**Electric Temperature Control and Detection Devices**

**SENSITIVE . . . *but only to heat***

# New Turbine-Powered Cargo Carrier

## hauls big pay loads faster

## Allison T56 Turbo-Prop Engines Power New Lockheed YC-130 Transport

The initial flight of the YC-130 Medium Cargo Transport marks another great forward stride in transport aviation.

This giant carrier, built by Lockheed for the U. S. Air Force, is the first U. S. A. F. cargo plane designed from the very beginning for Turbo-Prop engines.

Powered by four of the new Allison T56 Turbo-Prop engines, this great new cargo airplane can haul heavy pay loads long distances at speeds required by our new modern combat jet Air Force. It is ideally suited to carry many types of heavy military equipment, on either long-range operations or in close support of troops. It also can be fitted as a combat troop carrier or an ambulance plane. The YC-130 can operate from shorter runways with greater rate of climb than either reciprocating or Turbo-Jet engine aircraft.

All this, plus its economical use of lower cost fuel, label the Turbo-Prop engine as the "work horse" power for future transports. And Allison, with its unmatched experience in high-powered Turbo-Prop design and manufacture, today offers both T56 and T40 engines to serve a broad range of modern flight requirements.

GM GENERAL MOTORS Allison Division of General Motors, Indianapolis, Indiana

# THE PROOF IS IN THE PACKAGES!

Rohr has won fame for becoming the world's largest producer of ready-to-install power packages for airplanes – like the Lockheed Constellation, Douglas DC-7, the all-jet Boeing B-52 and other great military and commercial planes.

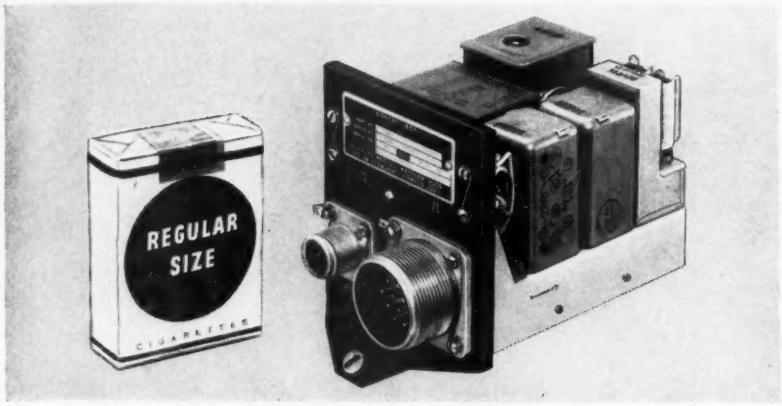
This, we believe, is proof of Rohr's engineering skill and production know-how. But it's not the whole story.

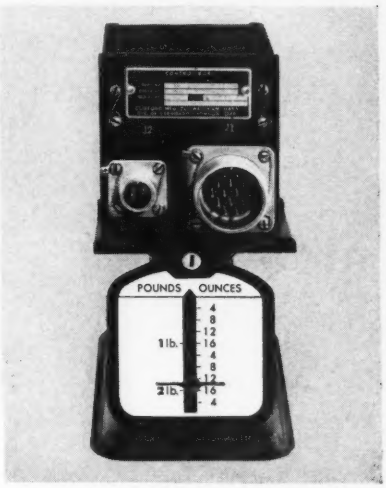
Currently, Rohr Aircraftsmen are producing over 25,000 different parts for aircraft of all kinds... many of these calling for highly specialized skill and specially engineered equipment.

Whenever you want aircraft parts better, faster, cheaper – call on Rohr. The proof of engineering skill and production know-how is in the thousands upon thousands of power packages that have made Rohr famous.

WORLD'S LARGEST PRODUCER OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES – *RECIPROCATING, TURBO-PROP, TURBO-COMPOUND AND JET.*

ROHR
AIRCRAFT CORPORATION
CHULA VISTA AND RIVERSIDE CALIFORNIA



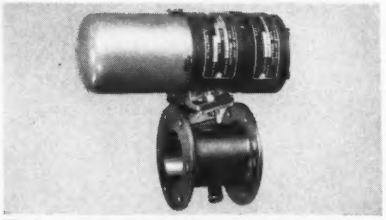

# Small, Lightweight Amplifier For Aircraft Temperature Control

## New Clifford unit features unitized construction, ruggedized, miniaturized components, novel pulse element

***Weighing only 28¾ oz.*** and measuring 4″ x 3⅛″ x 3″, Clifford's control box marks a number of advances in the field of aviation temperature control.

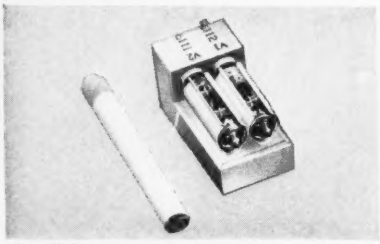
In addition to its small size and light weight, the control box design embodies several important advantages in service.

***Unitized construction*** makes it comparatively simple to locate a malfunction in service, quickly replace the unit containing the defective component, and get the plane back into the air.



***High temperature*** air valve and electric actuator.

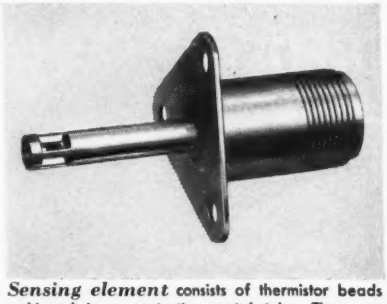
***Complete system*** of Clifford design and manufacture encompasses temperature sensing elements, temperature selector, control box and electrically actuated modulating valves.



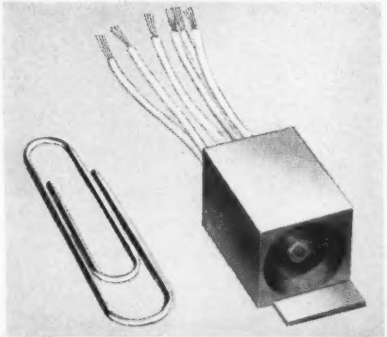
***Amplifier*** is small, compact, employs ruggedized tubes. Components are potted in resin.

***Miniaturized***, ruggedized components result in the smallest, lightest control possible for the job to be done. Elements within the box comprise an amplifier, which is highly compact and potted in resin, a novel pulse element smaller and lighter than comparable units, slave relays to operate valve actuators, a power supply, a calibration unit for the electrical bridge and a radio noise filter.

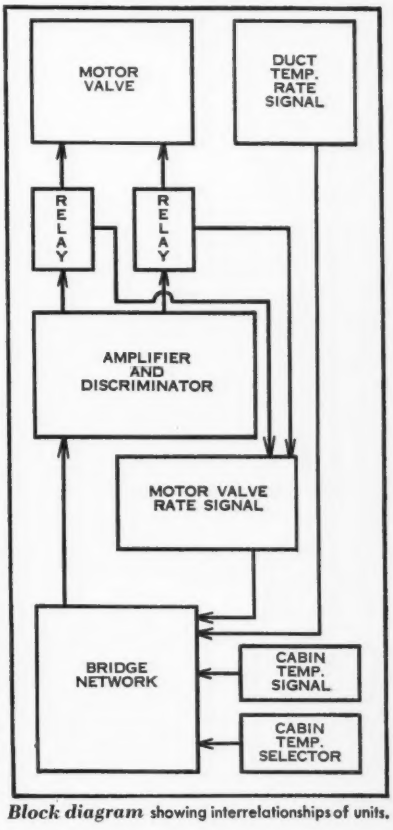
***Physical and electrical designs*** are both concerned with the performance-in-service factor. Electrical input values are held to optimum levels to insure long, trouble-free service. Physical arrangement of parts promotes maximum heat dissipation.



***Sensing element*** consists of thermistor beads cushioned in a protective metal tube. They are sensitive, accurate, small, long-lasting and protected against environmental conditions.



***Pulse unit*** is smallest of its kind and of novel design. Paper clip shows comparative size.




***Block diagram*** showing interrelationships of units.

***Information*** or consultation involving temperature control systems custom built to the requirements of specific aircraft on which you may be working is available without obligation.

Write: Clifford Manufacturing Company, 136 Grove Street, Waltham 54, Mass. *Division of Standard-Thomson Corporation.* 7.4.14

Bellows And Bellows Devices
CLIFFORD MANUFACTURING CO. WALTHAM, MASS.
DIVISION OF STANDARD-THOMSON CORP.
Aircraft Heat Exchangers Valves Electronic Equipment

POWER FOR MILITARY ROCKETS **by RMI**

Air to Air
Air to Surface
Surface to Air
Surface to Surface

# ROCKET POWERED KNOCKOUT

Military rockets must provide unfailing defense at supersonic speeds. RMI rocket propulsion can provide high performance meeting established military requirements.

RMI

RMI ENGINES POWER THE
[illegible] DOUGLAS [illegible]
MARTIN "VIKING" [illegible] & CONVAIR "LARK"
and various diversified projects

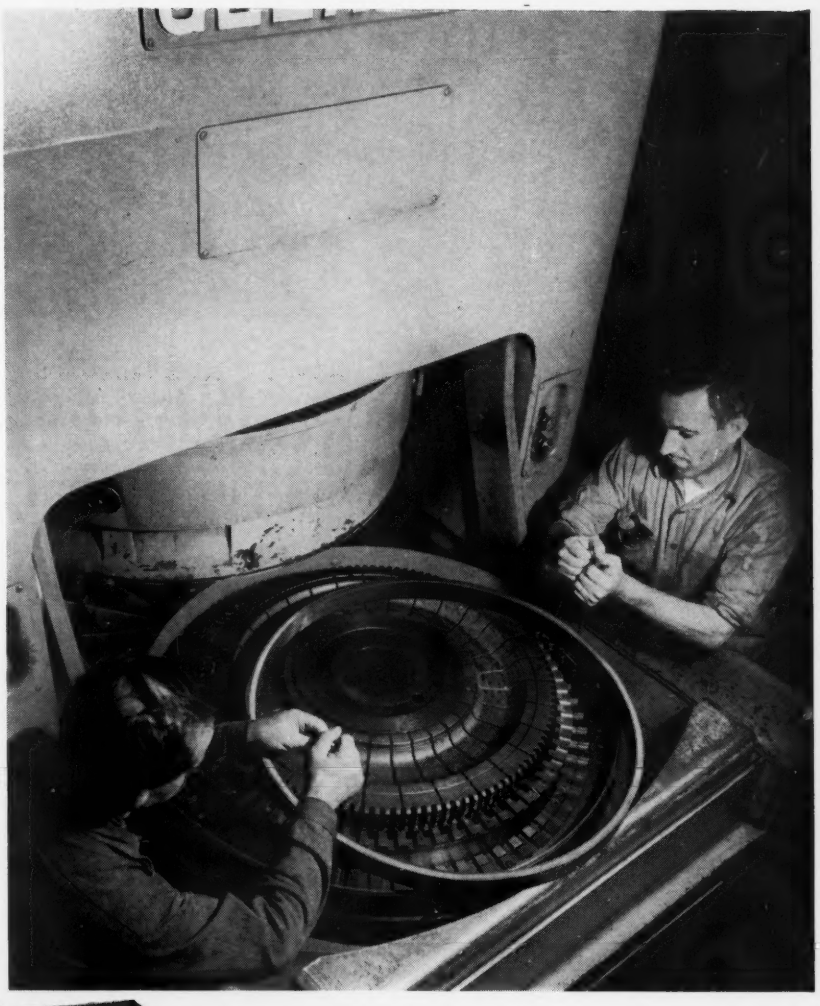
Missile boosters and sustainers
Aircraft powerplants
Ordnance rocket propulsion
Special propulsion devices
Launching and ejection devices
Auxiliary power units
Boundary layer control

**REACTION MOTORS, Inc.**

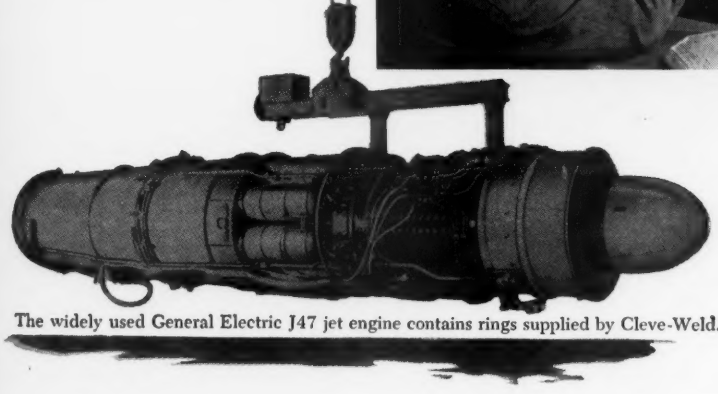
DENVILLE, NEW JERSEY

*Engineering Research Administration*

# Rings for jet engines ...by Cleve-Weld



The largest quench press of its kind prevents distortion during heat-treating and assures uniform structure of Cleve-Weld jet rings.



The widely used General Electric J47 jet engine contains rings supplied by Cleve-Weld.

An ever-increasing number of stainless steel and high-temperature alloy rings for America's jet engines are being produced by the Cleve-Weld Process. Use of Air Force-approved welding, heat-treating and machining equipment permits these rings to meet exacting physical and metallurgical tolerances.

That Cleve-Weld should be playing an important part in the production of welded rings for turbo-jet engines is not surprising. Certainly its nearly half-a-century of experience in the metallurgy and techniques of shaping and welding circular steel parts for many purposes uniquely fit it for such a role!

A 28-page illustrated brochure has just been prepared to provide prospective customers with a comprehensive picture of the engineering and production facilities which are here to serve their needs. All design, production and procurement executives concerned with jet engines are invited to send for a free copy. Write THE CLEVELAND WELDING COMPANY, West 117th Street & Berea Road, Cleveland 7, Ohio. (A subsidiary of American Machine & Foundry Company, New York)

products are better... *by design*

**The CLEVE-WELD Process**
*for better jet engine rings*

TOMORROW'S AIRCRAFT: *One step closer*

Drive power you can depend on . . . that's the keynote of the new line of Westinghouse 400-cycle, a-c motors. They deliver from 1/30 hp to 3 hp continuously from sea level to 50,000 feet—and raise performance standards to new highs in reliability and efficiency.

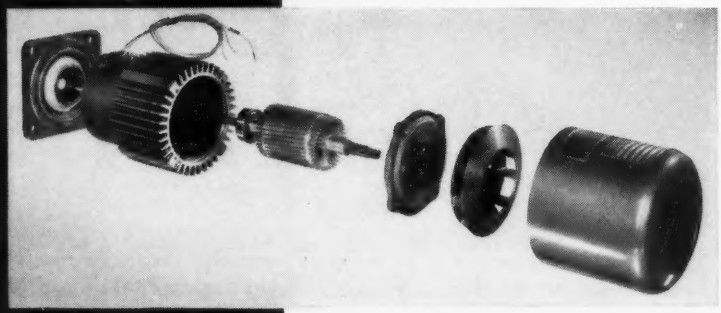
More horsepower than ever before has been packed into extremely small dimensions—like the four-inch diameter frame which delivers 3 hp and weighs under 10½ lbs. In spite of this small size and high rpm, temperature rise is kept exceptionally low by using new cooling techniques giving optimum thermal characteristics to produce the greatest possible horsepower per pound at *all altitudes.*

These new motors, designed to meet the requirements of specification MIL-M-7969, are totally enclosed, fan cooled and explosion-proof —ready-made for the most hazardous airborne applications. Sparks or flame caused by any abnormality cannot progress outside the motor. A patented method of flame suppression provides this same advantage on larger, open motors, over 3 hp.

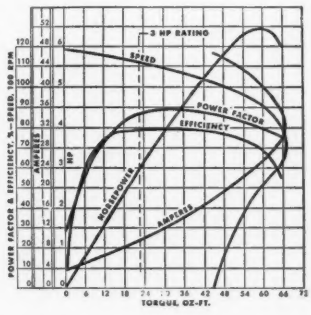
## Get More Information . . . NOW!

These new a-c motors—in ratings from 1/30 to 3 hp—are available NOW for direct drive and gear head applications. A drive you can depend on for vital controls and auxiliaries, they meet builder and user specifications with reserve to spare.

And Westinghouse will render full assistance in applying this new motor—the most advanced 400-cycle, a-c drive available today—to help you bring tomorrow's aircraft . . . One Step Closer. Get complete data and application information from your Westinghouse salesman or write Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-91016



The exclusive Westinghouse cooling design is built around an aluminum frame with integral fins. A new, efficient shrouded fan provides high volume cooling air flow. The rotor has extended conductor bars giving far more effective internal air circulation and cooling without added fan weight.




Performance curves for the 3-hp motor highlight the efficiency of these new a-c motors and their ability to handle loads from sea level to 50,000 feet. Greatly simplified and ruggedly designed, they handle even higher intermittent loads for temporary demands, especially at altitude.

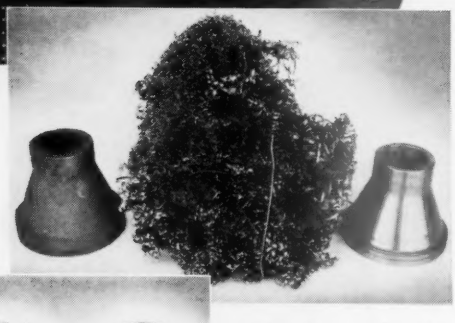
**Jet Propulsion • Airborne Electronics • Aircraft Electrical Systems and Motors • Wind Tunnels to Plastics**

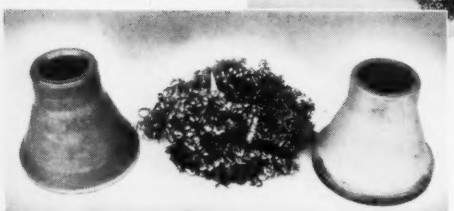
YOU CAN BE **SURE**...IF IT'S

# Westinghouse

**THE U. S. NAVY BUREAU OF AERONAUTICS, AND INDUSTRY, COMBINE TO ACHIEVE . . .**

# Reduced Cost and Improved Producibility for ROCKET POWER PLANTS





*The time and material savings for this one JATO part are illustrated by the "before" (above) and "after" (left) photographs.*

The U. S. Navy Bureau of Aeronautics has achieved impressive savings for the government and assured availability of rocket powerplants during emergencies by conducting at Aerojet-General a production engineering program resulting in reduced cost, elimination of strategic materials and facilities, and simplification of manufacturing processes. This program, directed primarily toward the new 15KS-1000 smokeless JATO, has been a significant part of Aerojet-General's effort to maintain high standards of quality and reliability while, at the same time, reducing costs and greatly expanding its production capacity to meet anticipated Department of Defense requirements.

**• SOLID- AND LIQUID-PROPELLANT ROCKET POWERPLANTS FOR MISSILE AND AIRCRAFT APPLICATIONS • THRUST REVERSERS (SNECMA) • AUXILIARY POWER UNITS AND GAS GENERATORS • ELECTRONICS AND GUIDANCE • ORDNANCE ROCKETS • EXPLOSIVE ORDNANCE AND WARHEADS • UNDERWATER PROPULSION DEVICES • ARCHITECT-ENGINEER SERVICES FOR TEST FACILITIES**

**Aerojet-General** CORPORATION

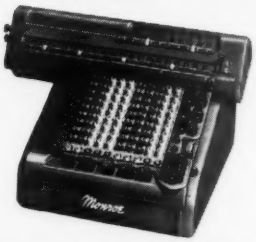
A Subsidiary of
The General Tire & Rubber Company

THE GENERAL TIRE

AZUSA, CALIFORNIA
CINCINNATI, OHIO
SACRAMENTO, CALIFORNIA

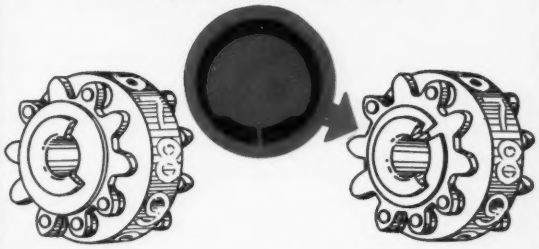
# Waldes Truarc rings replace old-fashioned fasteners . . . save assembly time...end scrap loss...increase operating efficiency

## This is the Monroe Calculator



...precision-engineered business machine made even more efficient, and less costly to manufacture through the use of Waldes Truarc Retaining Rings.

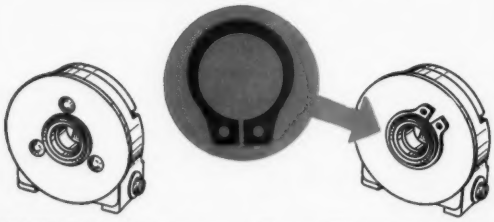
## Multiplier Dial Assembly



**Old Way.** One-piece assembly was spun together. Spinning operation was costly, resulted in high scrap loss.

**Truarc Way.** Two-piece assembly is held together by one Truarc Ring (series 5108). Rejects: practically zero.

## Electric Motor Governor



**Old Way.** Collector Disc assembly was formerly riveted, requiring skilled labor. Riveted Collector Disc could not be removed in the field.

**Truarc Way.** Truarc Ring (series 5100) replaces rivets, saves labor, material...improves Collector action. Collector Disc is easily replaced.

## Intermediate Gear Shaft

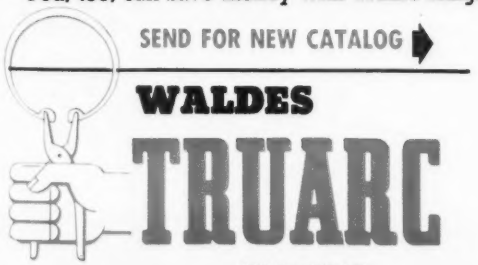
**Old Way.** Washer riveted on end of assembly for zoning control. Costly, troublesome, hard to obtain critical zoning required.

**Truarc Way.** Truarc E-Ring (series 5133) cuts assembly time, virtually eliminates rejects and final assembly and zoning problems.

Monroe Calculating Machine Company, Orange, N. J. uses various types and sizes of Waldes Truarc Retaining Rings. Use of Truarc has helped eliminate scrap losses, saved on material and labor, and resulted in increased operating and servicing efficiency of the product. Monroe plans to use Truarc Rings for every possible fastening operation on their entire line!

You, too, can save money with Truarc Rings. Wherever you use machined shoulders, bolts, snap rings, cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better, more economical job. Waldes Truarc Rings are precision-engineered...quick and easy to assemble and disassemble.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc Engineers for individual attention, without obligation.



SEND FOR NEW CATALOG

**WALDES**

**TRUARC**

REG. U. S. PAT. OFF.

**RETAINING RINGS**

WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS AND PLIERS ARE PROTECTED BY ONE OR MORE OF THE FOLLOWING U. S. PATENTS: 2,303,947; 2,382,948; 2,416,652; 2,420,921; 2,420,341; 2,439,785; 2,441,846; 2,455,165; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,509,091 AND OTHER PATENTS PENDING

**For precision internal grooving and undercutting...Waldes Truarc Grooving Tool!**

AE126

**Waldes Kohinoor, Inc.,** 47-16 Austel Pl., L. I. C. 1, N.Y.

Please send me the new Waldes Truarc Retaining Ring catalog.

*(Please print)*

*Name* .....

*Title* .....

*Company* .....

*Business Address* .....

*City* ..... *Zone* ..... *State* .....

# Real "PULL"

## ...3,000,000 Lbs. Worth

These forgings are fixtures for an enormous testing device that can exert 3,000,000 lbs. pull. They were forged and precision machined at NATIONAL FORGE to very close tolerances. As an example, there is less than .003 in. play in the threads top and bottom combined — considerably less than the specifications called for. To the customer, it means testing data will be more accurate and informative.

No matter what type of machining you require, whether large or small, simple or intricate, National Forge has the equipment and experience to turn it out to your complete satisfaction.

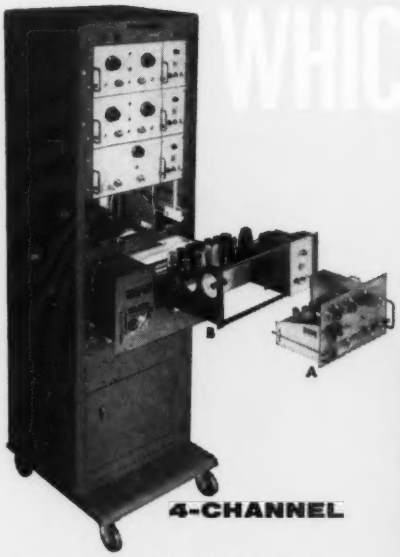
This is another example of National Forge's capacity for high precision machine work.

**NATIONAL FORGE AND ORDNANCE COMPANY**

PRODUCES BETTER STEEL FORGINGS AND MACHINE WORK

IRVINE, WARREN COUNTY, PENNSYLVANIA

# WHICH "150" fits your oscillographic recording need?




4-CHANNEL

As a graphic example of the design idea that has brought new versatility to industrial recording, a Carrier Preamplifier (A) is shown above in position to plug into a Driver Amplifier in framework with Power Supply (B) which are normally already in place in the Basic Cabinet Assembly.

The identical design principles of the four-channel system are provided in the two-channel, the only difference being the number of channels.

Sanborn "150" Recording Systems that put to use the original design concept of amplifier interchangeability (illustrated at the left) start with either a four-channel or two-channel standard Basic Assembly, to which the user adds whatever selection or combination of pre-amplifiers (A) are needed for his recording problem. The standard Basic Assemblies comprise a metal Cabinet, Recorder, and a built-in Driver Amplifier and Power Supply (B) for EACH channel. Presently available Preamplifiers are: AC-DC, Carrier, DC Coupling, Servo Monitor, Log-Audio, and Low Level Chopper.

Advantages common to ALL Sanborn Recorders are: inkless recording (by heated stylus) on plastic coated strip chart paper, and in true rectangular coordinates . . . high torque galvanometer movement . . . time and code markers . . . numerous paper travel speeds.

2-CHANNEL

"150"

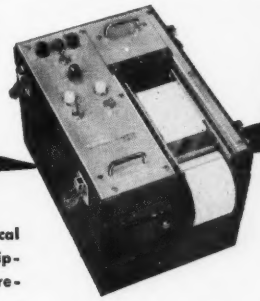
COMPLETE FOUR-CHANNEL SYSTEM FOR USE WITH ANALOG COMPUTERS

This "150" system consists of a Cabinet Assembly, a four-channel Recorder, and *two* dual channel DC Amplifiers. Each amplifier is complete with a common power supply. Each measures and records two separate single-ended signals, at sensitivities between one and one hundred volts per centimeter. The *two*-channel version of this system will comprise Cabinet, *two*-channel Recorder, and *one* dual channel amplifier.

"150"

SINGLE-CHANNEL RECORDER

A compact, lightweight unit for use when only one channel is required — provides permanent, inkless recording in *true* rectangular co-ordinates; *five* paper speeds (5, 10, 25, 50, 100 mm/sec.); *extra* stylus for either manual or remote timing and coding marks. Designed for simple, patch cord connection to *any* of the several "150" preamplifiers (plus driver amplifier and power supply), available soon in portable metal cases.



Ask, also, for a copy of the *Right Angle* — a Sanborn publication devoted to oscillographic recording in industry.

Catalog and technical data on all "150" equipment available on request.

**SANBORN COMPANY**

*Industrial Division*

**CAMBRIDGE 39, MASS.**

# FURY ON THE TRAIL

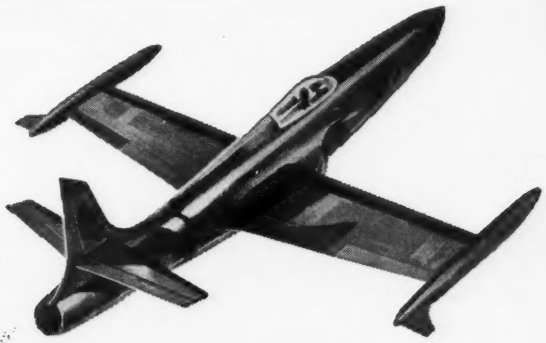
Purposefully, as if on a rendezvous with doom—as indeed it is—the guided missile blasts its way through the long reaches of the sky. The roaring flame is its power, but the "eyes" and "brain" that guide and control it are electronics.

RCA has cooperated for years with the armed forces to develop guided missiles of ever-increasing accuracy and effectiveness . . . the same mutual effort that is constantly being applied to creating, designing, developing and producing complete electronic systems in this and other fields relating to national defense.

Engineering consultation available.
Address Government Department,
Engineering Products Division, Camden, N. J.

RCA

GOVERNMENT DEPARTMENT
**RADIO CORPORATION of AMERICA**
ENGINEERING PRODUCTS DIVISION CAMDEN, N.J.



# Why JET ENGINES need Heat-Resistant Alloy Castings

Take a look at these castings...

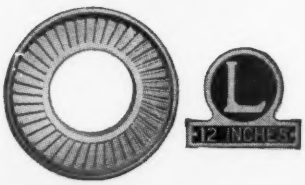
In each one, specific advantages are gained by casting the part in heat and corrosion-resistant alloy containing nickel.

Nickel-containing alloys are also specified for combustion chambers, nozzle vanes, flame tube casings, and other components subject to heavy stresses, intense heat, corrosion fatigue and other service conditions.

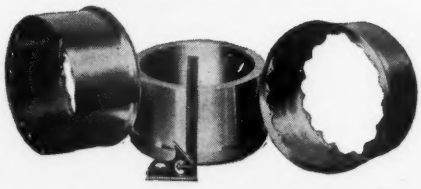
High alloy castings containing nickel may be of help to you on jobs where resistance to heat and corrosion are prime requisites. Send us details of your problems for our suggestions. Write today.

EMBLEM OF INCO SERVICE

**JET ENGINE DIFFUSER CONE**...produced by SOLAR AIRCRAFT COMPANY, San Diego, Calif., for use in J34 jet engines. Made from 18-8 columbium-stabilized stainless steel (AMS 5363) this casting replaced forgings, and resulted in greater economy plus superior dimensional stability of the part after machining. Diameter: 24 in —Weight: 200 lbs

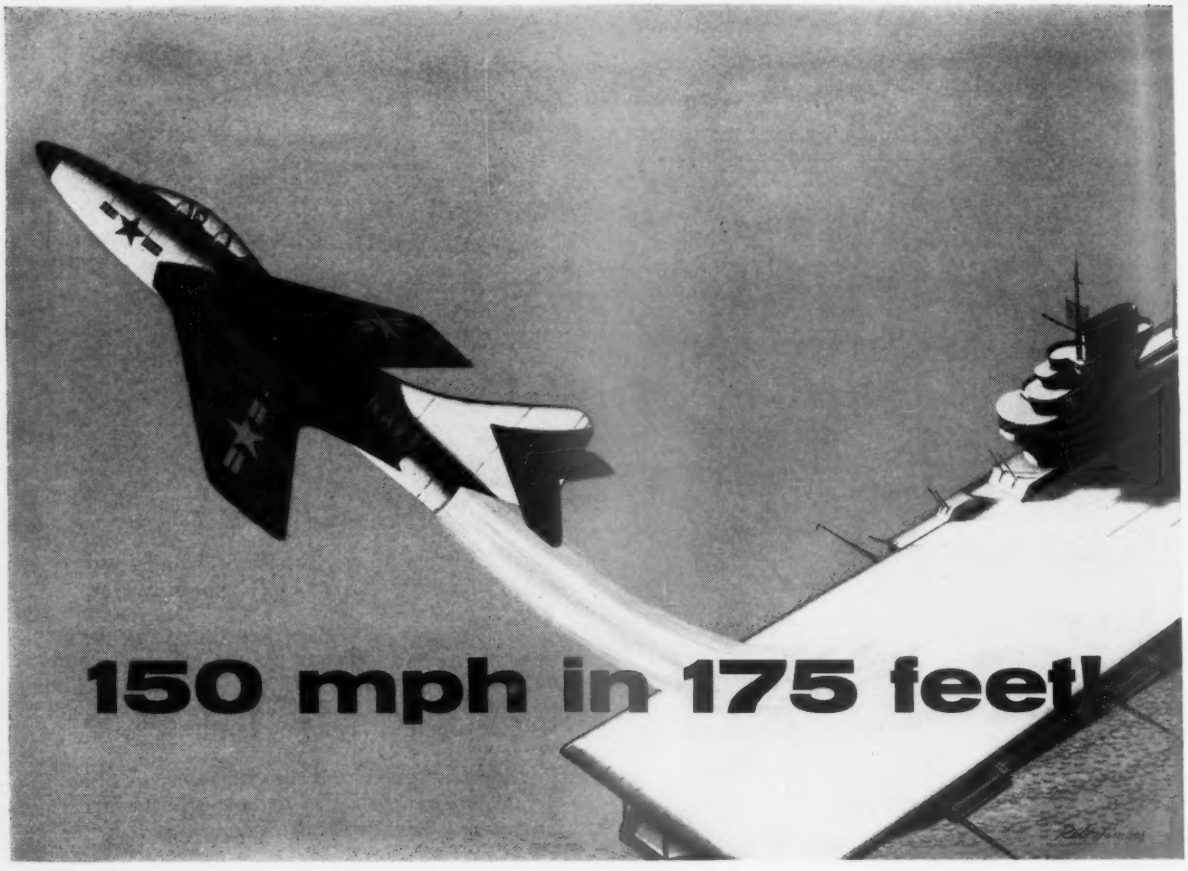



**NOZZLE DIAPHRAGM** . . . used in aircraft engines at temperatures up to 1600°F. Produced by LEBANON STEEL FOUNDRY, Lebanon, Pa., this part is cast in chromium-nickel stainless steel (CF-8C alloy, approximately equivalent to Type 347 wrought material).



**JET ENGINE RINGS** . . . centrifugally cast by the DURALOY COMPANY, Scottdale, Pa., using 25% chromium—14% nickel—3% tungsten alloy. The center casting is a rough machined blank. The end castings are finished rings. These parts are used at temperatures of 600°-700°F., under highly oxidizing conditions. Diamcter: about 15 in

**THE INTERNATIONAL NICKEL COMPANY, INC.** 67 WALL STREET NEW YORK 5, N. Y.




That is the speed at which the latest steam catapult launches a jet fighter. Such speed requires precision and split-second action to control the temperature and pressure of the steam which drives the catapult. Hagan Automatic Control has been chosen for this important function.

This is just one of the many specialized applications for which versatile Hagan control systems are ideally suited. A few recent applications of Hagan Automatic Control to aeronautical and automotive test facilities are listed below.

- Automatic control systems for subsonic and supersonic wind tunnels.
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- Automatic control systems for burner stands.
- Automatic control systems for parallel and/or series operation of blowers and exhausters.
- Programmed control systems for simulated flight conditions and trajectory tests.
- Automatic controls for gas turbines.
- Automatic control of pressure, pressure ratio, temperature and mass flow.
- Direct reading mass flow meters for both air and fuel, with automatic correction for variable pressure, temperature and density.
- Automatic resolution of multiple wide range correction factors into a single correcting signal.
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# WESTON Sensitrol® RELAYS CONTROL CRITICAL TEMPERATURES DIRECT FROM THERMOCOUPLE OUTPUT!




Hot dimpling of high stress materials for flush riveting used in today's airframes requires unfailing control of sheet temperatures within very close limits. Over temperatures might cause annealing and loss of strength, and under temperatures, inter-granular disorder and cracking.

To assure this precise and dependable control, Aircraft Tools, Inc. employ Sensitrol Relays in the Hot Dimpling Press illustrated, as well as in their portable dimpling tools. Operating directly from thermocouple output, these relays render the equipment inoperative should temperatures drop below a specified limit during dimpling; and also are used in the thermocouple break-circuit to prevent heater burn-out in case of thermocouple failure.

This is another instance where Sensitrol Relays have been adopted because they provide a positive means of control direct from feeble input signals . . . *without any amplification.* Some of their outstanding features are listed at the left. The complete story, in bulletin form, is available on request. WESTON Electrical Instrument Corporation, 614 Frelinghuysen Avenue, Newark 5, New Jersey. 8098

**Ultra-Sensitive SENSITROL Relays . . .**

- **Operate directly on values low as ½ microampere or ¼ millivolt.**
- **Handle substantial wattage at 110 volts on non-chattering magnetic contacts.**
- **Eliminate need for amplifiers and auxiliary power supplies.**
- **Available with single or double contacts, fixed or adjustable, manual or solenoid set.**

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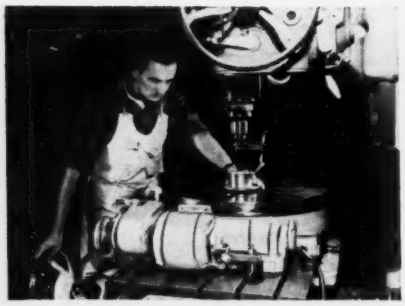
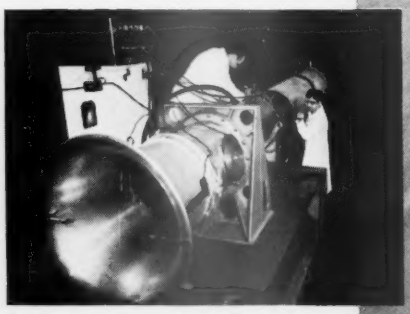
The J44 is a low-cost, easy to maintain engine capable of repeated flights and long-service-life. Its rugged construction withstands repeated launchings from ground cradles, shipboard catapults or from mother planes in the air.

Creative thinking and advanced design techniques incorporated in the J44 and other turbojets, as well as new type propulsion systems for underwater ordnance, keep the Fairchild Engine Division in the forefront of powerplant development.

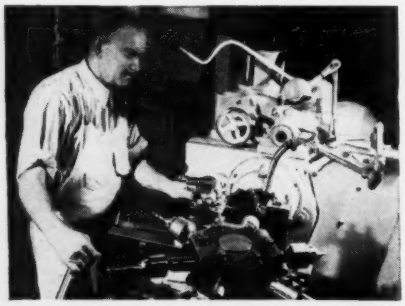
Fairchild J44 Turbojets have completed hundreds of operational flights in swept-wing Ryan Firebee target drones.



Efficient production design of the J44 Turbojet requires only standard tooling—means economical production.



In actual service the J44 has demonstrated performance far in excess of original engineered service life.



Fairchild Engine specialists have years of experience in powerplant design and manufacturing.

The simplicity of the J44 construction means easy field maintenance using only standard equipment.

ENGINE AND AIRPLANE CORPORATION

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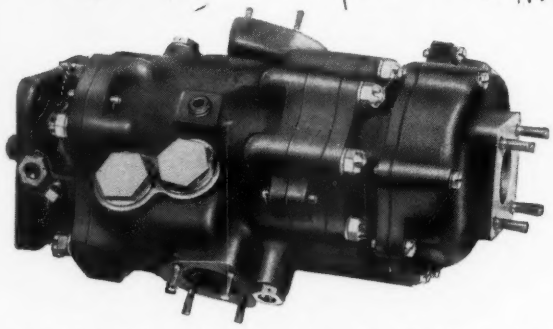
# FOR CONTINUOUS NEW PUMP PERFORMANCE *and* DEPENDABILITY...



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Bootstrap Refrigeration Unit

Cabin Supercharger

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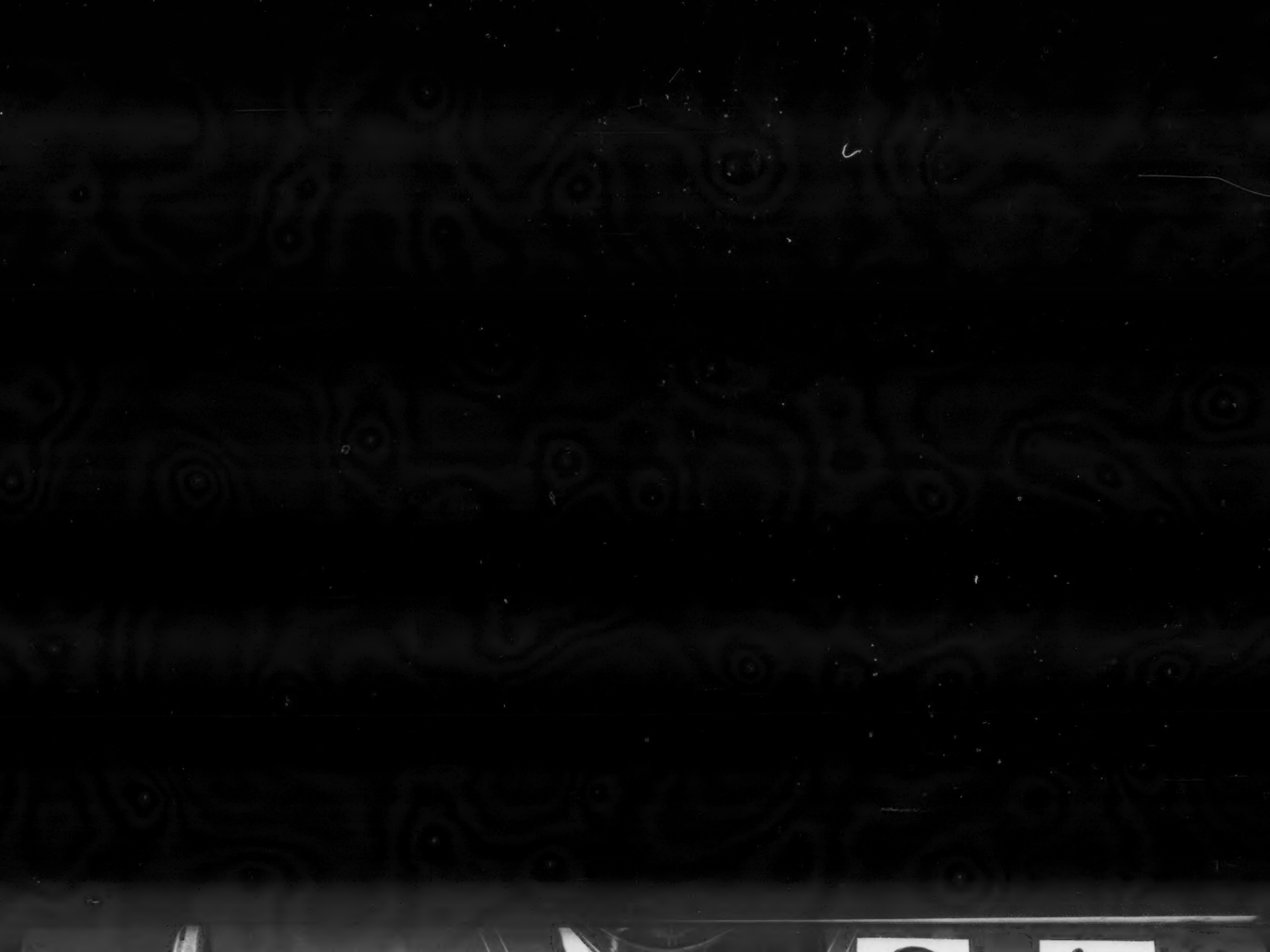
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